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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

FLOW CHARACTERISTICS AND LIMITATIONS OF ARMCO METERGATES

Hydraulic Laboratory Report No. Hyd-314

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

August 6, 1951

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CONTENTS

	Page
Purpose	1
Conclusions	1
Recommendations	2
Acknowledgment	3
Introduction	3
Investigation	3
The Laboratory Installations	3
The Analysis of the Problem	4
Preliminary Study on the 12- and 24-inch Metergates	5
The Outlet Submergence Limitation	6
Pressures in Corrugated Pipe	7
The Upstream Submergence Limitation	8
The Effect of Velocity Upon C_d	9
Influence of Corrugated Pipe on C_d	9
Influence of Approach Design on C_d	10
Result of Offsetting Measuring Well Tap	11
Distance Along Pipe to Uniform Velocity Distribution	11

	Figure
12-inch Armco Metergate Model No. 101	1
Laboratory Installation--Metergate Tests	2
Instrumentation Used in Testing Metergates	3
Laboratory Installation of 12-inch Metergate	4
Laboratory Installation of 24-inch Metergate	5
Laboratory Installation of 48-inch Metergate	6
Bellevue Hydraulic Laboratory	7
C_d vs. h/a 12-, 24-, and 48-inch Metergate at x/d = 2/3	8
Manufacturer's Detail Drawing	9
Manufacturer's Detail Drawing	10
Relationship of Effective Head and Gate Loss	11
Laboratory Installation 8-inch Corrugated Pipe Test	12
Recorded Pressure Head--Corrugated Pipe Test	13
Table 1, Pressures in Corrugated Pipe	14
Discharge Curve for 15-inch Metergate with Corrugated Pipe	15
C_d vs. R_e for 15-inch Metergate with Corrugated Pipe	16
C_d vs. R_e and C_d vs. h/a for 8-inch Metergate	17
Separation Zone Downstream of Gate	18
C_d vs. R_e for 12-, 15-, and 24-inch Metergates with Unconfined Entrance	19
C_d vs. R_e for 8-, 12-, and 15-inch Metergates with Unconfined Entrance	20
C_d vs. R_e for 15- and 24-inch Metergates with Confined Entrance	21
Coefficient Curve--8-inch Metergate	22
Coefficient Curve--12-inch Metergate	23
Coefficient Curve--15-inch Metergate	24
Coefficient Curve--24-inch Metergate	25

CONTENTS--Continued

	Figure
Common Approach Design U. S. B. R. Specification--Confined Entrance	26
Measuring Well Offset Studies	27
Distance to Uniform Volocity Distribution	28

APPENDIX

	Figure
Sample Computations for Metergate Installation	29
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 8-inch Metergate	30
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 10-inch Metergate	31
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 12-inch Metergate	32
Cd vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 14-inch Metergate	33
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 15-inch Metergate	34
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 16-inch Metergate	35
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 18-inch Metergate	36
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 20-inch Metergate	37
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 21-inch Metergate	38
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 24-inch Metergate	39
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 30-inch Metergate	40
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 36-inch Metergate	41
C_d vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 42-inch Metergate	42
Cd vs. R_e and Parameter ($D^2 \Delta Hg/\nu^2$) for 48-inch Metergate	43

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Branch of Design and Construction
Research and Geology Division
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August 6, 1951

Laboratory Report No. Hyd-314
Hydraulic Laboratory
Written by: J. B. Summers
Reviewed by: W. C. Case
J. W. Ball

Subject: Flow characteristics and limitations of Armco metergates

PURPOSE

To determine the flow characteristics and establish operation and installation limitations for various sizes of the Model 101 Armco metergate.

CONCLUSIONS

1. The published discharge tables used prior to the tests described in this report are in error as much as 18 percent.

2. To be used as a satisfactory flow-measuring device, a metergate must have sufficient submergence of the outlet to give a measurable water surface in the downstream measuring well. This required submergence varies with the differential head, the gate size, the gate opening, and the height of the measuring well bottom above the crown of the pipe.

3. The minimum outlet submergence and capacity for a metergate for given design conditions can be determined by procedure given in this report.

4. An outlet submergence of 1 foot is sufficient for all gate sizes, and openings at differential heads up to and including 18 inches when the bottom of the downstream measuring well is less than 6 inches above the crown of the pipe.

5. The outlet submergence does not affect the accuracy of the metergate.

6. The pipe downstream from a metergate should be at least 6 diameters long. This length is based on the data shown on Figure 28.

7. The test data taken from one size metergate cannot be analyzed by hydraulic similitude relationships and the results applied to other sizes because of geometrical dissimilarity of the gate assembly of the different sizes.

8. Four main factors influencing the accuracy of metergates may be shown by indicating their effect upon the coefficient of discharge, C_d, in the relationship,

$$Q = C_d A\sqrt{2g\Delta H}$$

as follows:

a. When the upstream water surface is less than one diameter above the crown of the pipe, C_d is not a constant. The deviation from a constant value is less for the smaller size metergates than the larger size. This conclusion is based on the results for gates with an unconfined entrance.

b. When the flow velocities are low (low Reynolds number), C_d is not a constant for a given gate opening, Figure 19B.

c. The corrugations in corrugated pipe influence C_d at gate openings between approximately 40 to 90 percent, Figures 23 and 24.

d. Approach designs (Figures 2 and 26) influence C_d at gate openings above approximately 50 percent, Figures 24 and 25. This influence was not evident on the 8-inch metergate, Figure 22. The results shown on the figures are for the conditions when the effects of upstream submergence and R_e are negligible.

9. The tap into the pipe 1 foot downstream from the gate seat to indicate the pressure head in the downstream measuring well should be on the top at the vertical center line because this location is used by the manufacturer and was that used in all except one test discussed in this report. This test disclosed that there was an error in discharge of as much as 3 percent if the tap is offset 3-1/2 inches from the vertical center line, Figure 27.

10. The hydraulic grade line of flow in corrugated pipe cannot be located by piezometric pressures taken in a crest (outer diameter) or valley (inner diameter) of a corrugation. The pressures indicated by piezometers placed in the crests read high while those placed in the valleys read low, Figures 12 and 13.

RECOMMENDATIONS

1. Use the new rating tables published by Armco Drainage and Metal Products, Inc., Denver, Colorado, unless the design conditions are different from those covered by the tables.

2. Use the information contained in this report to determine the capacity and limitations when the conditions are different from those covered by the manufacturer's tables. An example is contained in this report as Appendix I.

ACKNOWLEDGMENT

Studies were made on an 18- and a 48-inch Armco Metergate Model No. 101 at The Colorado Agricultural Research Foundation of Colorado A&M College, Fort Collins, Colorado, by Mr. Sol D. Resnick under the general supervision of Dr. Maurice L. Albertson. Some of the data obtained from these studies are included in this report. The metergate studies by the Bureau were made jointly by members of the Canal and Research and Geology Divisions. The Armco Drainage and Metal Products, Incorporated, furnished the 8-, 12-, 15-, and 24-inch metergates used in the Bureau tests.

INTRODUCTION

With thousands of acres of arid land being developed annually for agricultural purposes, the necessity for accurate distribution of the limited supply of water has become a problem of paramount importance. The increased demand for water created by new irrigation projects and the gradual lowering of the ground-water table in some locations has made it necessary to provide means for economical distribution. One requirement for economical distribution is accurate measurement of flow to the land at a minimum cost.

One common measuring device is the metergate. The simplicity of design and low maintenance cost has resulted in its extensive use, both for measuring and regulating irrigation water. The metergate can be attached to corrugated pipe or to the smooth pipe of a concrete structure. When used as a measuring device, two 10-inch measuring wells, 2 feet or higher, are attached to the framework on the downstream side of the gate. One measuring well provides a means for recording the water surface upstream of the gate, while the other well indicates the pressure head 1 foot downstream of the gate seat. Figure 1 shows a metergate with the gate leaf in full open position, the measuring wells, and a 2-foot section of corrugated pipe.

INVESTIGATION

The Laboratory Installations

A schematic drawing of the installation for the metergates tested by the Bureau is given in Figure 2. The flow was provided to the test gate by three 12-inch and one 8-inch centrifugal pumps. It was necessary to use all of these pumps in the testing of the 24-inch metergate. The discharge was determined by venturi meters

installed near each pump. The sizes of the venturi meters used in the studies were 6, 8, 12, and 14 inches, thus making accurate flow measurements possible over a wide range. The venturi meters had been recently calibrated. The flow after passing through the rock baffle in the head box of the test installation had good distribution and a negligible velocity of approach to the metergate. To obtain pressures in the pipe downstream of the metergate, piezometers with a 1/8 inch inside diameter were installed at intervals on the top normal to the inside surface. The piezometric pressures were transferred by rubber tubing to a manometer board (Figure 3A) which was positioned with its zero on the pipe center line. The manometer board was scaled to 0.01 foot which made possible readings to the nearest 0.005 of a foot. Fluctuations in pressure in the piezometer representing the downstream measuring well had to be damped considerably since it was necessary to get accurate water surface readings. This was accomplished by inserting 3/4-inch diameter carborundum disks in a plastic cylinder in the line leading from the piezometer to the manometer board. About ten readings were taken for each test run to obtain average values for the piezometric pressures.

On the outlet of the installations there was a tail box with a movable gate with which to raise or lower the hydraulic grade line. The tests were made over a range of approximately 2- to 36-inch differences in water surfaces in the measuring wells. The 8-, 12-, and 15-inch metergates were tested with 1-inch increments of gate opening and the 24-inch metergate with 2-inch increments. The indicator used to show the amount of gate opening is shown in Figure 3B. On the 12- and 24-inch gates, a section of transparent plastic was installed downstream from the gate so that the flow conditions below the gate could be observed, Figures 4 and 5. The plastic section was attached downstream of the corrugated pipe on the 12-inch gate while on the 24-inch gate it was attached directly to the gate seat.

The test installation used by Colorado A&M College to test the 48-inch metergate is shown in Figure 6. The flow was provided by diverting water from the Cache la Poudre River through the concrete test flume, Figure 7. The discharge was determined by means of a steel weir located at the outlet end of the test flume.

The Analysis of the Problem

The Hydraulic Laboratory studies were made to establish installation limitations, such as the necessary outlet submergence, and to extend the manufacturer's rating tables.

As a basis for evaluating the flow characteristics and limitations of the metergates, the following relationship was used:

$$Q = C_d \frac{\pi d^2}{4} \sqrt{2g\Delta H}$$

where: Q = discharge, cfs
C_d = coefficient of discharge
d = nominal diameter of gate, feet
g = gravity, 32.2 ft/sec^2
ΔH = difference in water surface in measuring wells, feet

From the initial analysis of the problem, it was concluded that the coefficient of discharge, C_d, would be influenced by the following variables which are defined in Figure 2; the upstream submergence, h; the gate opening a, the nominal diameter of gate, d; the location of downstream measuring well, x, measured from the gate seat; and the mean velocity in the pipe, V To facilitate the use of the variables, h, a, d, x, and V, they were put into dimensionless parameters with this resulting relationship:

$$C_d = \phi(h/a, a/d, x/d, R_e)$$

The parameter, R_e, is the Reynolds number and is obtained from the following relationship:

$$R_e = \frac{Vd}{\nu}$$

V = mean velocity in the pipe, ft/sec
d = nominal diameter of gate, feet
ν = kinematic viscosity ft^2/sec

The advantage of using R_e rather than V or Q was that the viscosity factor takes the temperature of the fluid into consideration, and R_e is a common parameter used to compare hydraulic data.

It was anticipated that the limitations of installation and operation for all sizes of metergates could be established with a satisfactory degree of accuracy by investigating the above parameters on a 12-inch metergate and apply the laws of similitude. However, early in the investigation it was found that the similitude relationships could not be applied because of differences in the gate assembly of the various sizes so a range of sizes were tested.

Preliminary Study on the 12- and 24-inch Metergates

The initial test results on the 12-inch gate revealed a discrepancy with the rate of flow for a particular ΔH and gate opening given in the manufacturer's tables. The 12-inch metergate was tested with a 2-foot section of corrugated pipe attached to the gate seat, and the next gate (24-inch) was tested with 4 feet of transparent plastic pipe placed immediately downstream from the gate seat to determine the effect of smooth and corrugated pipe. The test results from the 24-inch gate also showed a disagreement with the manufacturer's tables as did those obtained for the 18-inch and 48-inch gates at Colorado A&M College. Since this discrepancy in some instances was as much as 18 percent, a comprehensive study was deemed

necessary to prepare new tables for all the gate sizes. The initial results on these gates also revealed that the discharge curve deviated from a straight line on logarithmic paper at low ΔH's. This deviation was later determined to be the effect of R_e and upstream submergence as will be discussed in subsequent parts of this report.

The results of the tests on the 12- and 24-inch metergates and those obtained at Colorado A&M College were compared by making a plot of C_d versus h/a at corresponding gate openings (a/d x 100). The resulting plot is shown in Figure 8. The C_d used in this plot was based on ΔH measured at a point downstream from the gate seat, arbitrarily selected, equal to an x/d of 2/3. Upon this basis, geometric similarity was satisfied providing the metergates were geometrically similar. The plot showed some variation of C_d with h/a, indicating that the upstream submergence, h, influenced C_d, and that some geometric dissimilarity existed between gates of different sizes. The curves were horizontal straight lines above a critical value of h/a, the point where h did not influence C_d. However, the values of C_d for the metergates above this critical value of h/a differed by 10 percent at some relative gate openings, a/d, a factor considered indicative of geometrical dissimilarity.

The fact that the 12- and 48-inch metergates were tested with corrugated pipe and the 24-inch metergate with smooth pipe was not overlooked, but it was believed that the variation in the pipe roughness could not cause all the C_d difference. The geometric similarity of the metergates was then investigated. Examination of the manufacturer's drawings, Figures 9 and 10, revealed that geometric similarity did not exist between the metergates of different sizes and this would explain the source of much of the discrepancy in the plot of C_d versus h/a.

This discussion on dissimilarity should not be construed as meaning poor design of the metergates, because other factors besides similitude must be considered in the designs, but to indicate that some other method of analysis must be applied to the laboratory study. The decision finally reached was to make further tests on an 8- and a 15-inch metergate, and to determine the characteristics of other sizes by interpolation and extrapolation of the results from the six sizes

The new procedure of analyzing the test data was to base the C_d on the ΔH measured at x = 12 inches for all sizes tested. This made the parameter, x/d, a variable, and the results for one gate comparable to those for the other sizes only by interpolation or extrapolation.

The Outlet Submergence Limitation

The tests on the several gate sizes disclosed an important limitation, namely, that of providing ample outlet submergence, h_s. Figure 2, for the differential heads ΔH at which the metergates

were expected to operate. The outlet submergence must be sufficient to provide a measurable water surface in the downstream measuring well, arbitrarily selected as 6 inches above the top inside surface of the pipe. The submergence necessary for this condition was found to vary directly with the magnitude of ΔH. Figure 11 gives the information for determining the required submergence for a given gate installation. Examination of this figure will show that the greatest submergence is required for gate openings of approximately 40 to 60 percent. With the 6-inch minimum level in the downstream well and a given gate size and discharge, a maximum value of ΔH must be determined as outlined in the appendix of this report. The required outlet submergence h_s can be determined using this ΔH. It will be (ΔH + 6 inches) minus H_d. An example is given in the appendix.

The determination of the required outlet submergence for the gates attached to corrugated pipe was difficult in that the hydraulic grade line of the flow was not indicated by piezometers placed in either the crests or valleys of the corrugations. A series of tests were made to determine the influence of the corrugations on the piezometric pressures. The analysis of the data was based on the results of these tests which are discussed in the following section of this report.

Pressures in Corrugated Pipe

In the tests having corrugated pipe attached to the gate seat, analysis of the pressure data was difficult due to the local pressure variations in the corrugations. The pressures indicated by a piezometer located in the crest (most distant point from pipe center line) of a corrugation were different from those indicated in the valley (closest point to pipe center line). The distance between the crest and valley was 1-1/3 inches for all pipe sizes. Confronted with this condition, it was concluded to make tests on a section of corrugated pipe to establish some basis upon which an evaluation of the data could be made.

The installation used for the study is shown in Figure 12. The smooth steel pipe upstream and downstream from the corrugated section was provided with piezometers to locate the hydraulic grade line. Nine piezometers were located in the corrugated section, five in the crests of corrugations and four in valleys. The piezometer designated No. 5 was installed to represent the construction used by the manufacturer on the downstream measuring well tap and to observe the effects of such an installation. This was done by placing a piezometer normal to the pipe axis and extending it through the pipe wall to a position referred to as the nominal diameter. The 1/2-inch-radial space surrounding the piezometer tube inside the pipe was filled with solder, Figure 12.

Figure 13 illustrates the results of tests conducted on this installation. The pressures are given for two discharges, Q = 1.32 cfs and Q = 4.09 cfs. A comparison of the two runs indicates that the large variation in pressures at Q = 4.09 cfs must be the effect of the velocity. Although no tests were made to confirm this conclusion, it seems

logical that the pressures in the crest were indicating a partial velocity head due to the impingement of the flow on the valley side in addition to the static pressure, and the pressures in the valley were actually less than the static pressure due to a slight separation. The dashed line connecting the hydraulic grade lines of the smooth pipe was assumed to be the corrugated pipe gradient, which was approximately the mean value of the crest and valley pressures. Interpolations of the metergate data concerning required outlet submergence were based upon this assumption. The error involved was believed to be negligible. The pressure indicated by a piezometer installed, such as No. 5, Figure 12, is the same as for a piezometer located in the crest. This can be observed readily in Figures 13 and 14. Figure 14 gives the pressures for various discharges.

However, tests discussed in a subsequent part of this report indicate that C_d is not influenced by the corrugations at the full gate opening. This can be explained by the fact that the tap for the downstream measuring well is located in the vena contracta zone which is controlled in shape and character by conditions other than the corrugations.

This test on corrugated pipe is not a comprehensive study because of limited facilities at the time and the immediate need of the information. There is no doubt that the length of an 8-inch corrugated pipe test section should be longer than 4 feet in order for the flow to assume its natural distribution.

The Upstream Submergence Limitation

During the testing, logarithmic plots were made of discharge versus difference in head (ΔH) for the different sizes of gates at various openings. These plots gave straight lines for the higher values of ΔH, but a variable deviation from a straight line at small values of ΔH and h as shown in Figure 15. This characteristic was particularly noticeable on the 24-inch metergate. The effect was observed visually by noting the change in ΔH at a given flow when the tail gate setting was changed to raise or lower the hydraulic grade line, including the head box water surface. Although the flow remained constant ΔH was different. This condition explains at least part of the deviation of the discharge curve from the straight line. In other words, the same discharge will be obtained at different values of ΔH by increasing or decreasing h, when the value of h is relatively small.

The equation of the curve on the graph shown in Figure 15 is:

$$Q = C_d \frac{\pi d^2}{4} \sqrt{2g\Delta H}$$

Any change in ΔH at a constant discharge must be the result of a variable C_d since there was no change in the pipe diameter, d, or the gravitational force, g.

As the value of h was increased in the critical region, the deviation from the straight line became smaller and was negligible when the value of h was twice or more the diameter of the pipe. As previously stated, the effect was more pronounced on the 24-inch gate than on the smaller sizes tested in the Bureau laboratory. Other examples of the effect of h upon C_d are given in Figures 16 and 17. In Figure 16 a plot of C_d versus R_e at the 100-percent gate opening shows the effect upon C_d of varying h at a constant value of R_e.

Slight inconsistencies were noted in the test data for low upstream submergence (h less than 2d). This was attributed to unsteady flow conditions in the entrance. If accuracy is a paramount consideration the gates should be installed to provide a submergence of at least one pipe diameter above the crown or $h > 2d$, since any correction would be difficult and at best only approximate.

The Effect of Velocity Upon C_d

In the initial analysis, the assumption was made that the velocity of the flow would be one of the variables influencing C_d because the velocity would effect the separation zone shown in Figure 18. Since the downstream measuring well is located 1 foot from the gate seat, the value of ΔH is generally influenced by conditions within the separation zone. For simplicity of evaluation the mean velocity was chosen. This mean velocity is included in the dimensionless parameter R_e and this parameter was used in the study.

The results of the studies are shown in Figures 19 to 21, inclusive. As stated on the figures, the curves are for two influencing conditions, namely, pipe roughness and approach design. The procedure used in attempting to separate the influence of R_e upon C_d from the upstream submergence effect was as follows: The value of h was held greater than 2d by using the tail gate to shift the hydraulic grade line and varying R_e in the lower range. A deviation of C_d with R_e was apparent. This deviation is illustrated on Figure 19B At high values of R_e or discharge, the curve is a straight line since any factors effecting C_d are small, but in the lower range of R_e there is an apparent effect upon C_d. The deviation of C_d attributable to R_e is also included on Figure 15. This influence has been considered in the preparation of the new rating table.

Influence of Corrugated Pipe on C_d

The comparison of smooth and corrugated pipe was made on the 12- and 15-inch metergates. The effect of the pipe corrugations upon C_d is indicated in Figures 23 and 24. These curves of C_d versus percent gate opening were based upon the plots made of C_d versus R_e illustrated in Figures 19 and 20, at Reynolds numbers

where the value of C_d was constant. This constant value of C_d is beyond the critical zone where the influence by h (upstream submergence) and R_e is negligible. The maximum deviation between the two curves of C_d is approximately 7 percent on the 12-inch metergate. The effect of the pipe corrugations was evident between 40 to 90 percent of the gate opening. The effect upon C_d can be explained by the fact that the zone of separation is influenced in shape and character by the pipe roughness, thus influencing ΔH from which C_d is obtained. Below the 40-percent gate opening the separation zone covers a much longer portion of the pipe, and the pressure in the vicinity of the measuring tap was relatively constant. Above the 90-percent opening the influence of the shape of the gate frame (angle iron, etc.) of the metergate upon the contraction region immediately downstream is apparently more dominant than the corrugations of the pipe.

Influence of Approach Design on C_d

Since it was expected that some variation in C_d might be attributed to the approach design, a test was made on one of the most common approach designs and compared to the unconfined entrance of Figure 2. The approach design shown in Figure 26, which is a part of Bureau of Reclamation Specifications No. 2838, was used for this purpose. The effect of this approach upon C_d as compared to that of the unconfined approach is shown in the plot of C_d versus percent gate opening in Figures 22, 24, and 25. The tests revealed no influence by approach design on the 8-inch metergate, provided the upstream submergence was sufficient to give a uniform velocity distribution approaching the entrance, which was not the case for points 1, 2, and 3 on Figure 17. However, the effect is quite evident on the 15- and 24-inch metergates above 50-percent gate opening. This is a result of changes in the streamlines approaching the gate entrance which influenced the zone of separation. The fact that the approach effect was not indicated in the 8-inch metergate tests is understandable since the dimensions of the design, Figure 26, were held constant for all sizes tested, thus giving relatively less confinement of the entrance of the smaller sizes. The effect of variation in approach designs would not be noticeable at the small gate openings. More recent laboratory tests on gates similar to the metergates revealed the walls of the approach shown in Figure 26 as compared to the unconfined entrance in Figure 2 to cause a greater effect upon C_d than the floor arrangement of the two designs if the submergence was sufficient to give uniform velocity distribution. Tests made with the floor of Figure 26, but without the approach walls, indicate results comparable to those of the unconfined entrance shown in Figure 2. The deviation in C_d from that for the unconfined entrance at full gate opening increased with the gate size, from 0 percent for the 8-inch, 6 percent for the 15-inch, to 9 percent for the 24-inch metergate.

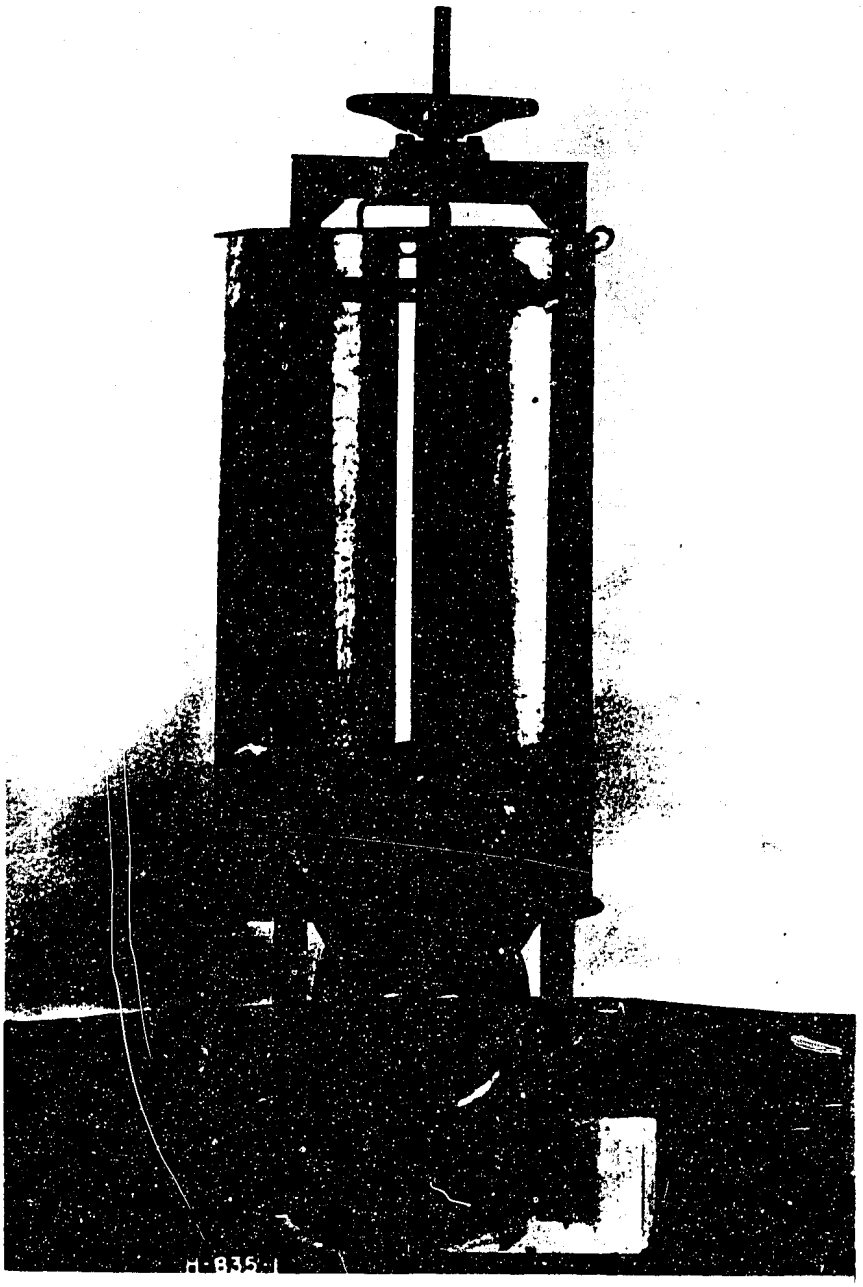
Result of Offsetting Measuring Well Tap

Tests on a well installation similar to that indicated in Section B-B, Figure 26, were made on the 24-inch metergate with smooth pipe attached to the gate. The results are shown on Figure 27. The testing was not extensive, but the results clearly indicated an error in discharge of as much as 3 percent was introduced with the offset piezometer installation. All published rating tables are based on the measuring well tap being located on the top. The reason for the difference in pressure in the two piezometers, both located 1 foot downstream from the gate seat, was the result of a variation in the velocity of the flow along the pipe surface, created by the protrusion of the gate slide into the flow at partial openings (20-inch, Figure 27) and the framework of the metergate structure at the full open position.

Distance Along Pipe to Uniform Velocity Distribution

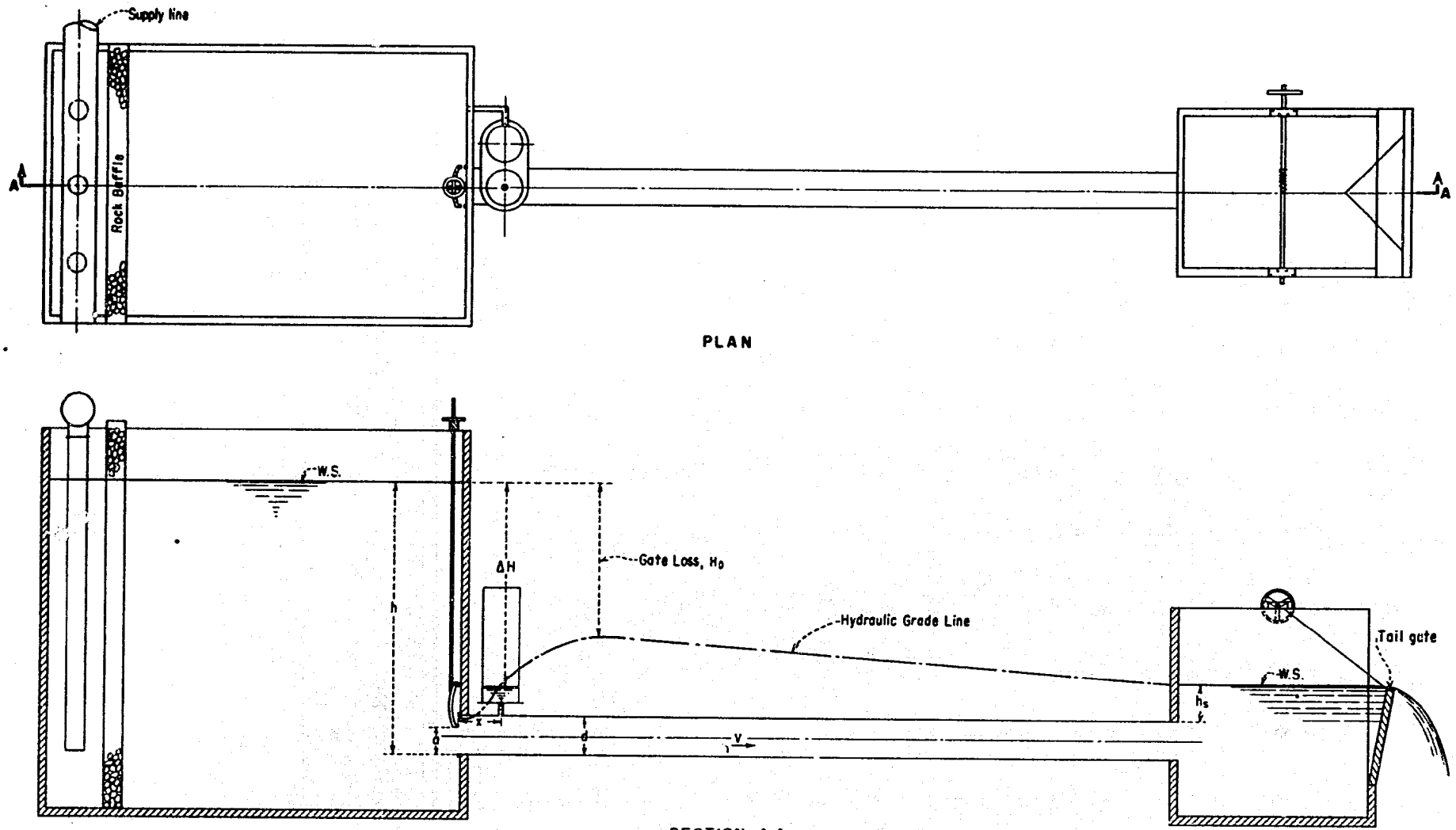
The pressure distribution in the pipe downstream of the gate was recorded for all gates tested in order to determine the minimum length of pipe required for satisfactory operation. The minimum length would be that required to attain uniform velocity in the pipe at all gate openings. The results of these tests are shown on Figure 28, from which it was concluded that six diameters could be used as a criterion. The plotted points were based on laboratory piezometric data, from which the point of establishment of uniform velocity was estimated, thus the curves are not as smooth as might be expected. The importance of this test was to make certain that an installation will have sufficient pipe length to minimize erosion at the outlet and to prevent sweeping the water out of the downstream measuring well at partial gate openings.

FIGURE 1
REPORT HYD. 314



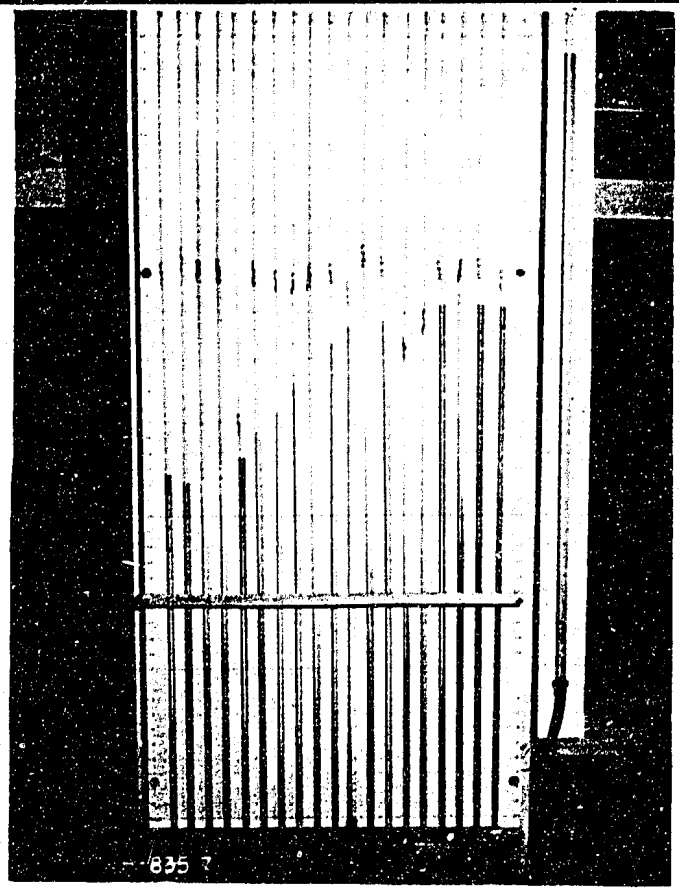
Metergate Studies

12-INCH ARMCO METERGATE MODEL NO. 101



METERGATE STUDIES
LABORATORY INSTALLATION METERGATE TESTS

FIGURE 2
REPORT HYD. 314

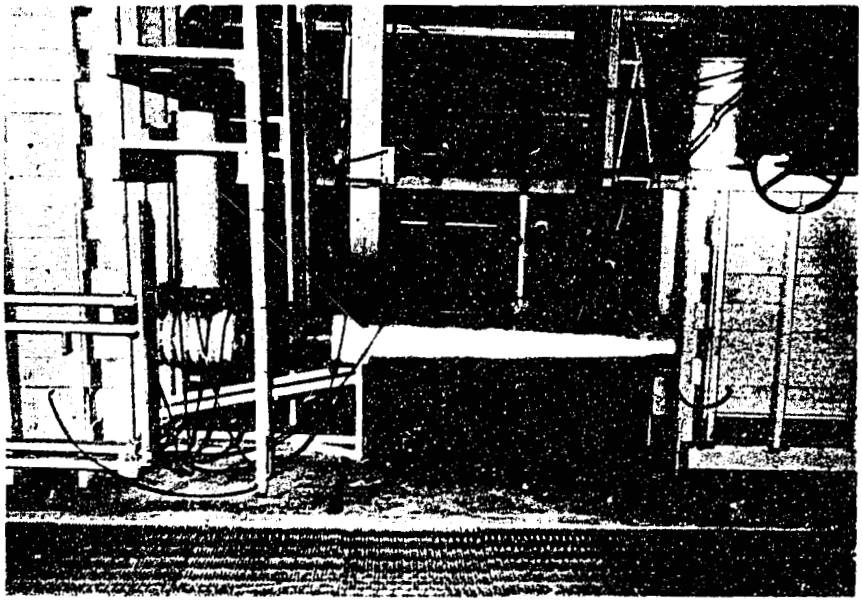


A. Manometer Board to indicate pressures along pipe-24-inch metergate

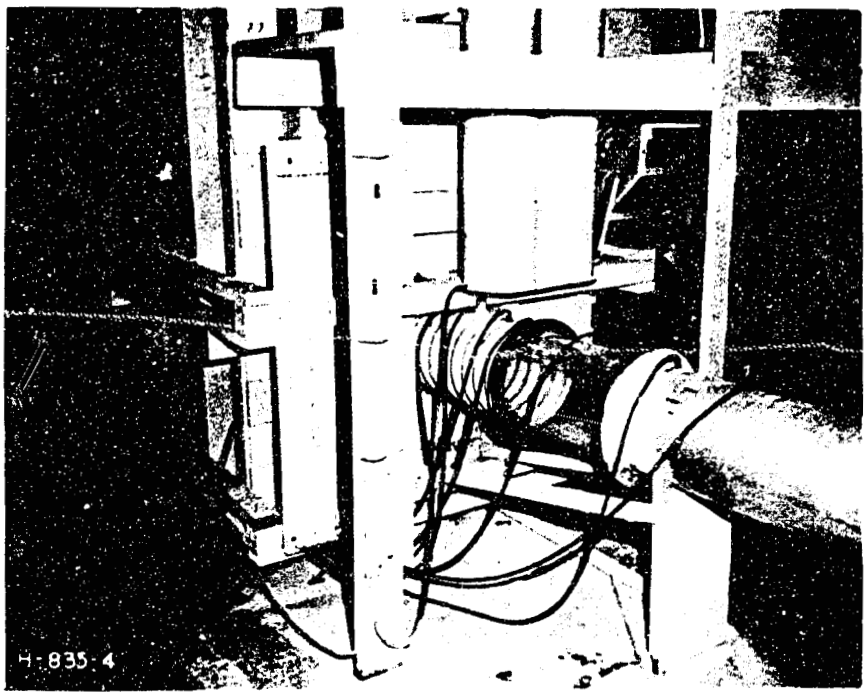
B. Indicator to measure gate opening-12-inch metergate

Metergate Studies

INSTRUMENTATION USED IN TESTING METERGATES



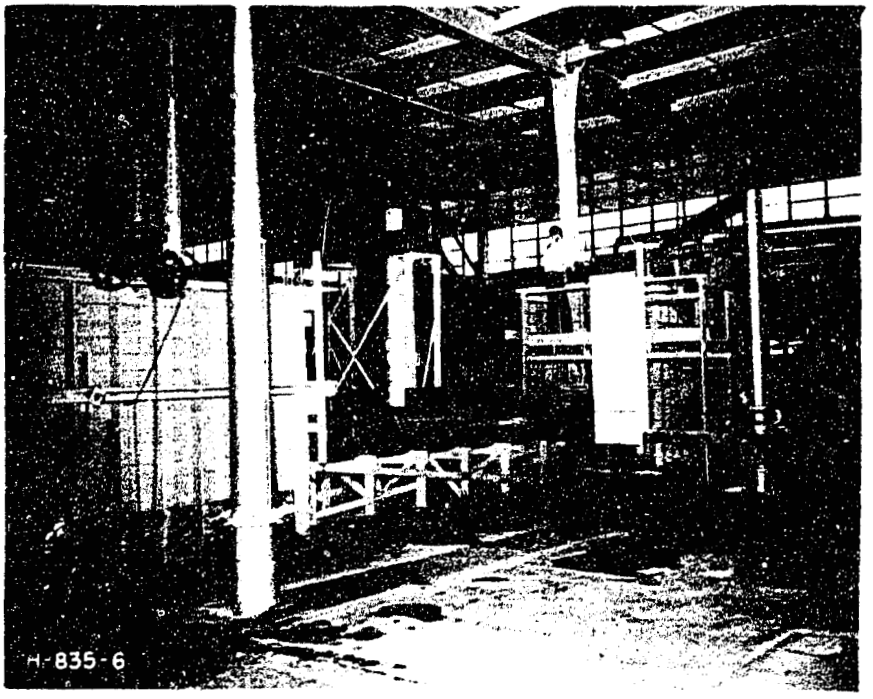
A. Side view of 12-inch metergate



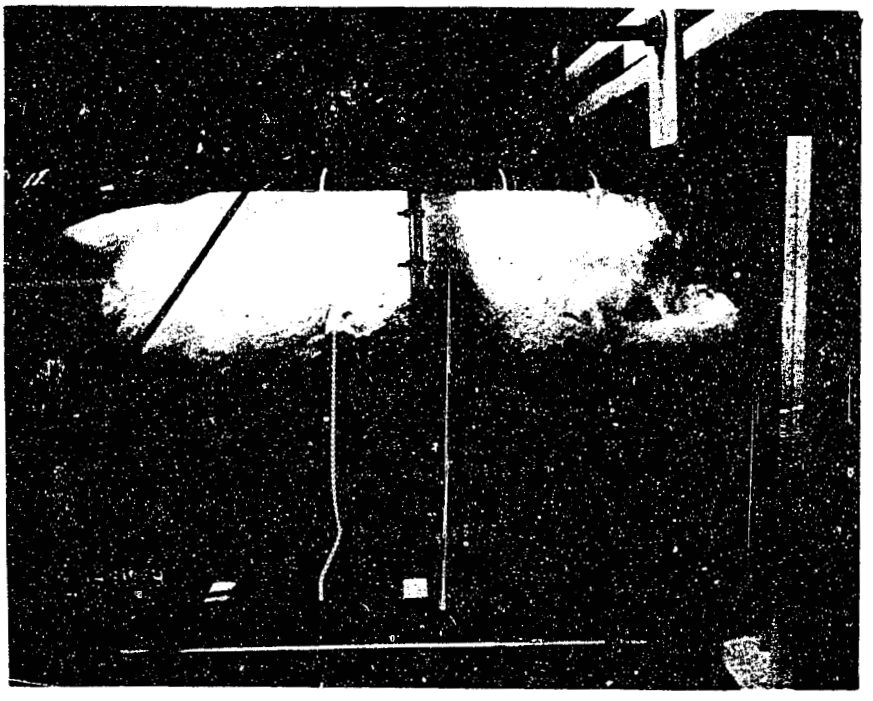
B. Close up 12-inch metergate

Metergate studies

LABORATORY INSTALLATION OF 12-INCH METER GATE



A. General view 24-inch metergate

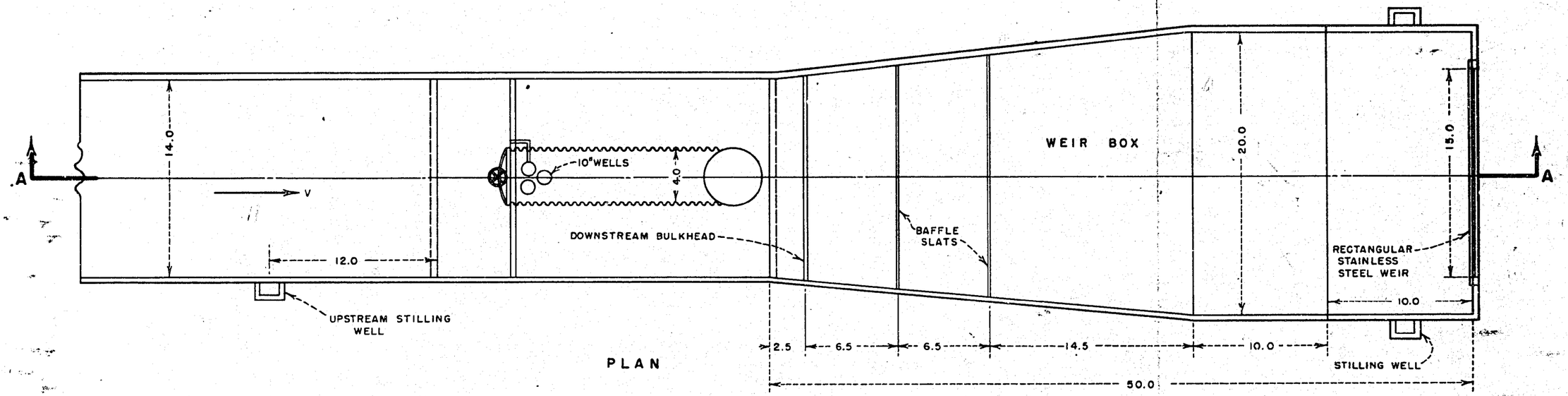


B. Air admitted immediately downstream of gate to illustrate turbulence. 12-inch gate opening Q= 15 c.f.s.

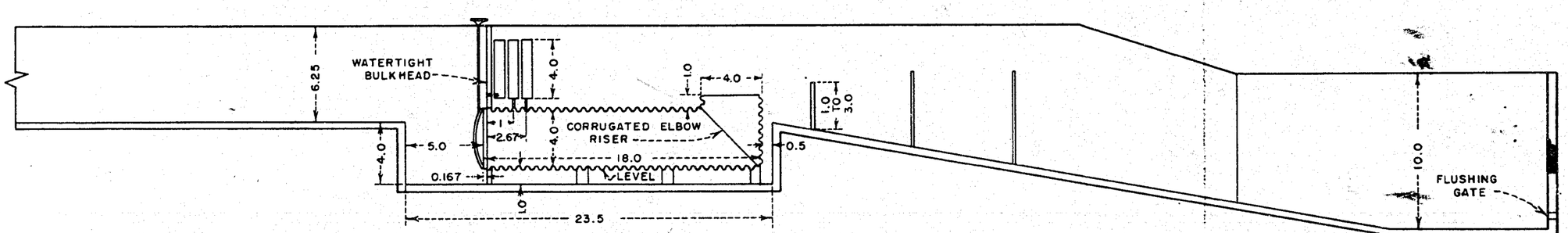
Metergate Studies

LABORATORY INSTALLATION OF 24-INCH METERGATE

FIGURE 6
REPORT HYD. 314



PLAN

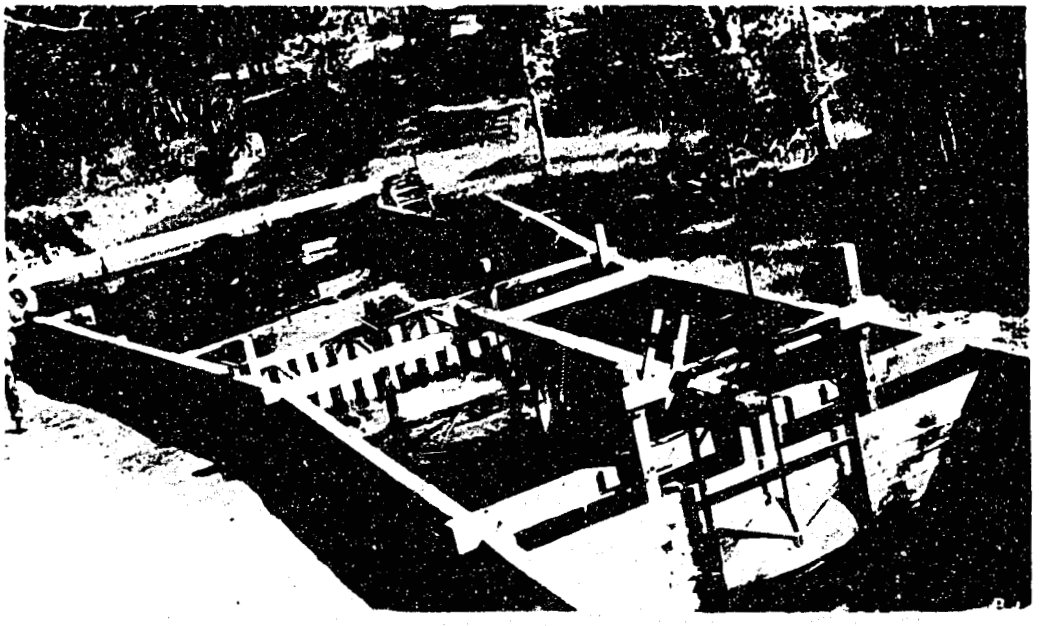


SECTION A-A

5 0 5 10
SCALE OF FEET
1:50

CALIBRATION STUDIES OF
48-INCH ARMCO METERGATE MODEL No. 101
COLORADO A. & M. COLLEGE
HYDRAULICS LABORATORY
FORT COLLINS, COLO. DEC. 1950

A. Bellevue Hydraulic Laboratory, Fort Collins, Colorado

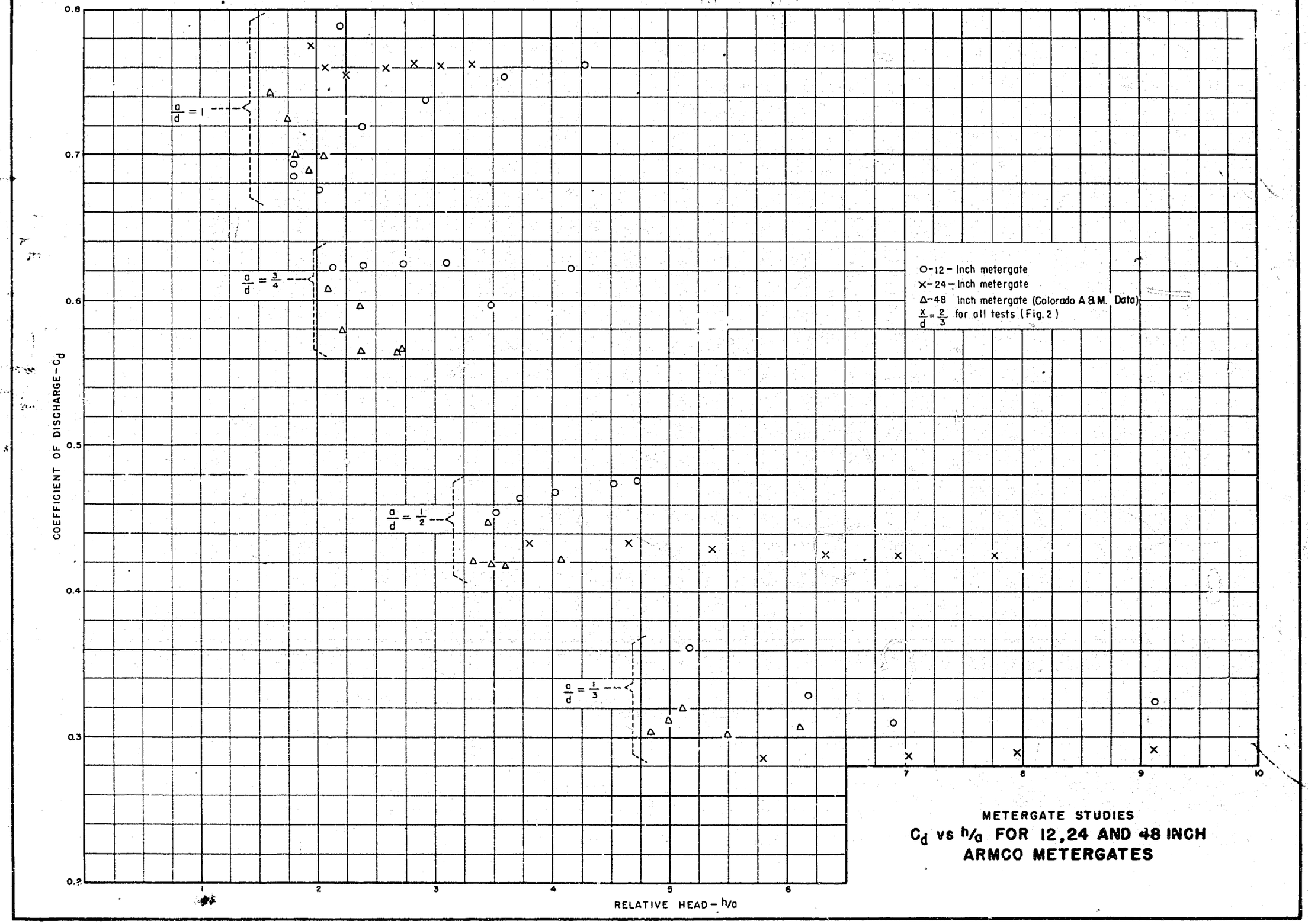


B. Test Flume with 48-inch metergate in foreground

Metergate Studies

LABORATORY INSTALLATION OF 48-INCH METERGATE

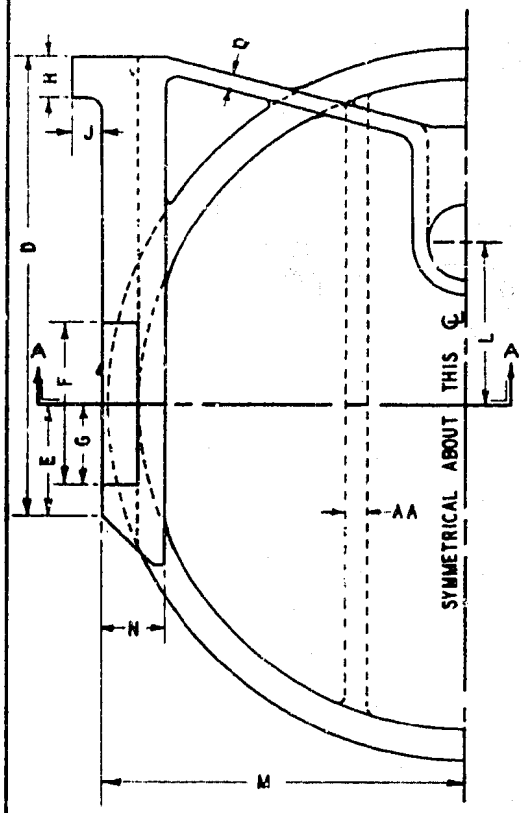
COLORADO A & M COLLEGE

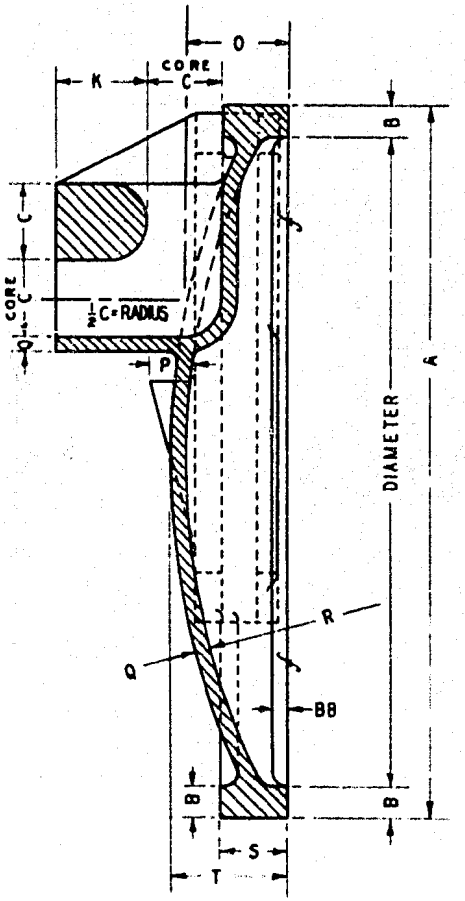


METERGATE STUDIES

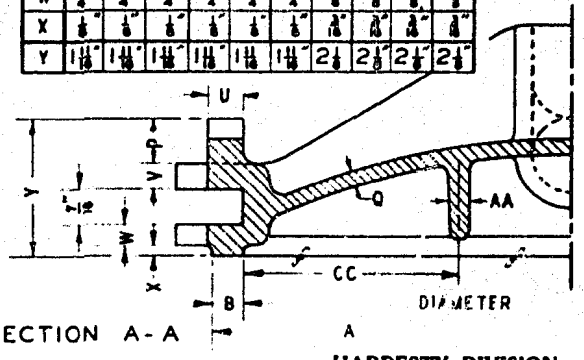
C_d vs h/a FOR 12, 24 AND 48 INCH ARMCO METERGATES

DIM. FOR RIBS				
DIA	18"	20"	21"	24"
AA	3/16"	1/8"	1/8"	1/8"
BB	1/8"	3/16"	3/16"	3/16"
CC	6"	6 3/8"	7"	8"





DIMENSION TABLE											PATTERNS CHANGES
DIA	8"	10"	12"	14"	15"	16"	18"	20"	21"	24"	NO.
A	8 3/4"	10 3/4"	12 3/4"	14 3/4"	15 3/4"	16 3/4"	19"	21"	22"	25"	8" 526
B	3/8"	3/8"	3/8"	3/8"	3/8"	3/8"	1/2"	1/2"	1/2"	1/2"	10" 513
C	15/16"	15/16"	15/16"	15/16"	15/16"	15/16"	1 1/16"	1 1/16"	1 1/16"	1 1/16"	12" 510
D	5 3/8"	7"	8 5/16"	9 1/16"	9 15/16"	10 7/8"	12 5/8"	13 5/16"	13 15/16"	15 1/16"	14" 1021
E	1 5/8"	1 3/4"	2"	2"	2"	2"	2 1/2"	2 1/2"	2 1/2"	2 3/4"	15" 526
F	2"	2"	2"	2"	2"	2"	2 1/2"	2 1/2"	2 1/2"	2 1/2"	16" 1490
G	1"	1"	1"	1"	1"	1"	1 1/4"	1 1/4"	1 1/4"	1 1/4"	18" 530
H	1/2"	1/2"	1"	1"	1"	1"	1 1/2"	1 1/2"	1 1/2"	1 1/2"	20" 1488
J	3/8"	3/8"	3/8"	3/8"	3/8"	3/8"	1/2"	1/2"	1/2"	1/2"	21" 532
K	1 1/8"	1 1/8"	1 1/8"	1 1/8"	1 1/8"	1 1/8"	1 5/8"	1 5/8"	1 5/8"	1 5/8"	24" 534
L	2"	2 1/2"	3"	3 1/2"	3 3/4"	4"	4 1/2"	5"	5 1/4"	6"	
M	4 5/8"	5 5/16"	6 1/16"	7 1/16"	7 11/16"	8 5/16"	9 5/8"	10 5/8"	11 1/8"	12 5/8"	
N	3/4"	3/4"	3/4"	3/4"	3/4"	3/4"	1 1/4"	1 1/4"	1 1/4"	1 1/4"	
O	1 1/4"	1 1/4"	1 1/4"	1 1/4"	1 1/4"	1 1/4"	1 11/16"	1 11/16"	1 11/16"	1 11/16"	
P	3/16"	3/16"	3/16"	3/16"	3/16"	3/16"	1/4"	1/4"	1/4"	1/4"	
Q	3/16"	3/16"	3/16"	3/16"	3/16"	3/16"	1/4"	1/4"	1/4"	1/4"	
R	9"	13 3/4"	17 5/8"	22 7/16"	25 1/4"	28 1/16"	32 1/4"	34 1/2"	38"	45 1/2"	
S	15/16"	7/8"	7/8"	15/16"	7/8"	1 1/16"	1 1/16"	1 1/16"	1 1/16"	1 1/4"	
T	1 7/16"	1 3/8"	1 1/2"	1 7/16"	1 7/16"	1 7/16"	1 7/8"	2"	2"	2 1/8"	
U	7/16"	7/16"	7/16"	7/16"	7/16"	7/16"	9/16"	11/16"	9/16"	11/16"	
V	3/8"	3/8"	3/8"	3/8"	3/8"	3/8"	3/8"	3/8"	3/8"	3/8"	
W	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	3/8"	3/8"	3/8"	3/8"	
X	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/16"	1/16"	1/16"	1/16"	
Y	1 11/16"	1 11/16"	1 11/16"	1 11/16"	1 11/16"	1 11/16"	2 1/16"	2 1/16"	2 1/16"	2 1/16"	



SECTION A-A

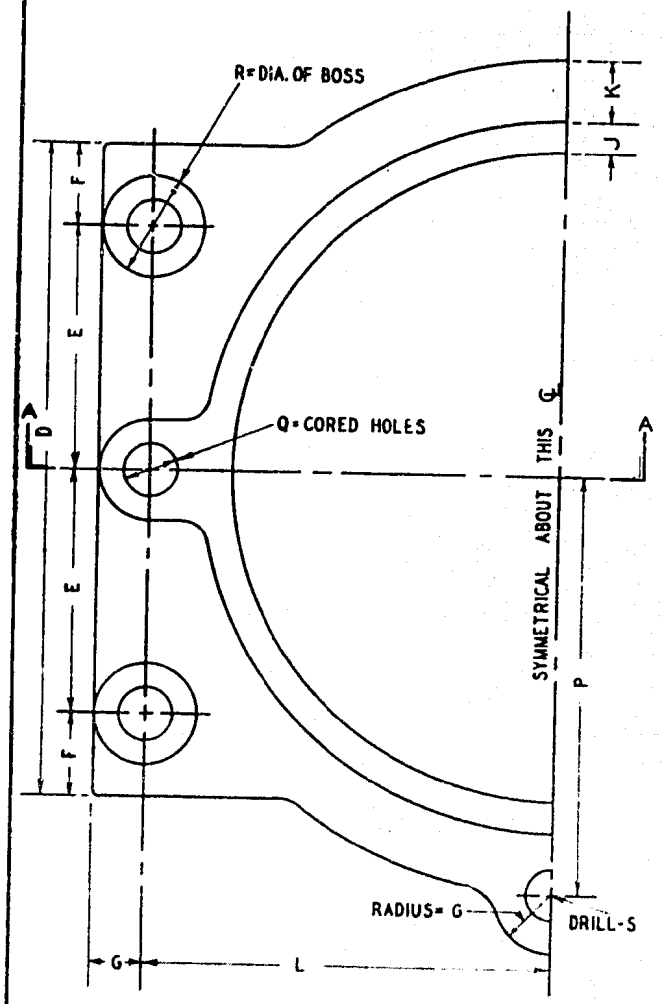
HARDESTY DIVISION
ARMCO DRAINAGE & METAL PRODUCTS, INC.
successors to

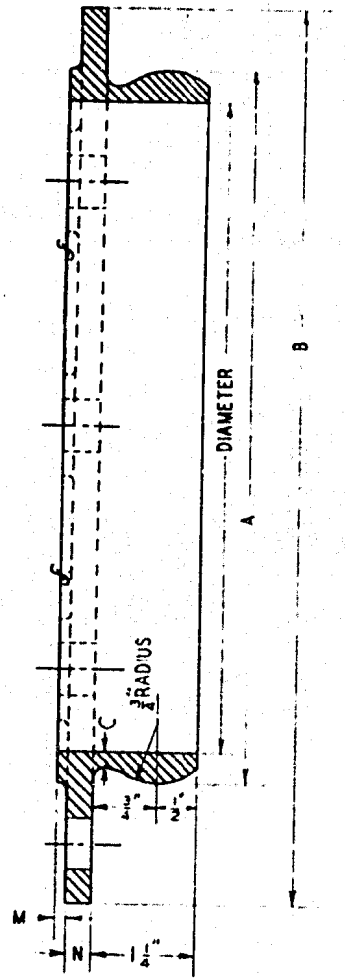
THE R. HARDESTY MFG. CO.
DENVER, COLO.

DETAILS OF SLIDE CALCO 101
8" TO 24" DIA CAST IRON

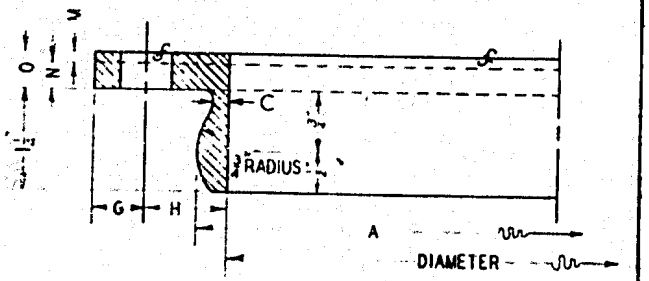
REVISED	DRAWN BY	TRACED BY	SCALE	ORDER NO.
	A.L.S.		NONE	
	CHECKED BY	APPROVED	DATE	DWG. NO.
	R.A.F.		11-24-43	12-428

REPORT HYD. 314 FIGURE 5





DIMENSION TABLE												
DIA	8"	10"	12"	14"	15"	16"	18"	20"	21"	24"	PATTERNS NO	PATTERNS CHANGES
A	8 3/4"	10 3/4"	12 3/4"	14 3/4"	15 3/4"	16 3/4"	18 3/4"	20 3/4"	21 3/4"	24 3/4"	8" 1094	
B	10 7/8"	12 7/8"	14 7/8"	16 7/8"	17 7/8"	18 7/8"	21 7/8"	23 7/8"	24 7/8"	27 7/8"	10" 1093	
C	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	12" 1092	
D	8"	9"	10"	11 1/2"	12"	13"	14 1/2"	16 1/2"	16 1/2"	18 1/2"	14" 1626	
E	3"	3 1/2"	4"	4 3/4"	5"	5 1/2"	6"	7"	7"	8"	15" 1091	
F	1"	1"	1"	1"	1"	1"	1 1/4"	1 1/4"	1 1/4"	1 1/4"	16" 1489	
G	5/8"	5/8"	5/8"	5/8"	5/8"	5/8"	7/8"	7/8"	7/8"	7/8"	18" 1090	
H	1"	1"	1"	1"	1"	1"	1 1/2"	1 1/2"	1 1/2"	1 1/2"	20"	
J	3/8"	3/8"	3/8"	3/8"	3/8"	3/8"	1/2"	1/2"	1/2"	1/2"	21" 1089	
K	3/4"	3/4"	3/4"	3/4"	3/4"	3/4"	1"	1"	1"	1"	24" 1088	
L	5"	6"	7"	8"	8 1/2"	9"	10 1/2"	11 1/2"	12"	13 1/2"		
M	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	3/16"	3/16"	3/16"	3/16"		
N	5/16"	5/16"	5/16"	5/16"	5/16"	5/16"	7/16"	7/16"	7/16"	7/16"		
O	7/16"	7/16"	7/16"	7/16"	7/16"	7/16"	5/8"	5/8"	5/8"	5/8"		
P	5 1/8"	6 1/8"	7 1/8"	8 1/8"	8 5/8"	9 1/8"	10 1/2"	11 1/2"	12"	13 1/2"		
Q	5/8"	5/8"	5/8"	5/8"	5/8"	5/8"	3/4"	3/4"	3/4"	3/4"		
R	1 1/4"	1 1/4"	1 1/4"	1 1/4"	1 1/4"	1 1/4"	1 3/4"	1 3/4"	1 3/4"	1 3/4"		
S	5/8"	5/8"	5/8"	5/8"	5/8"	5/8"	3/4"	3/4"	3/4"	3/4"		



SECTION A-A

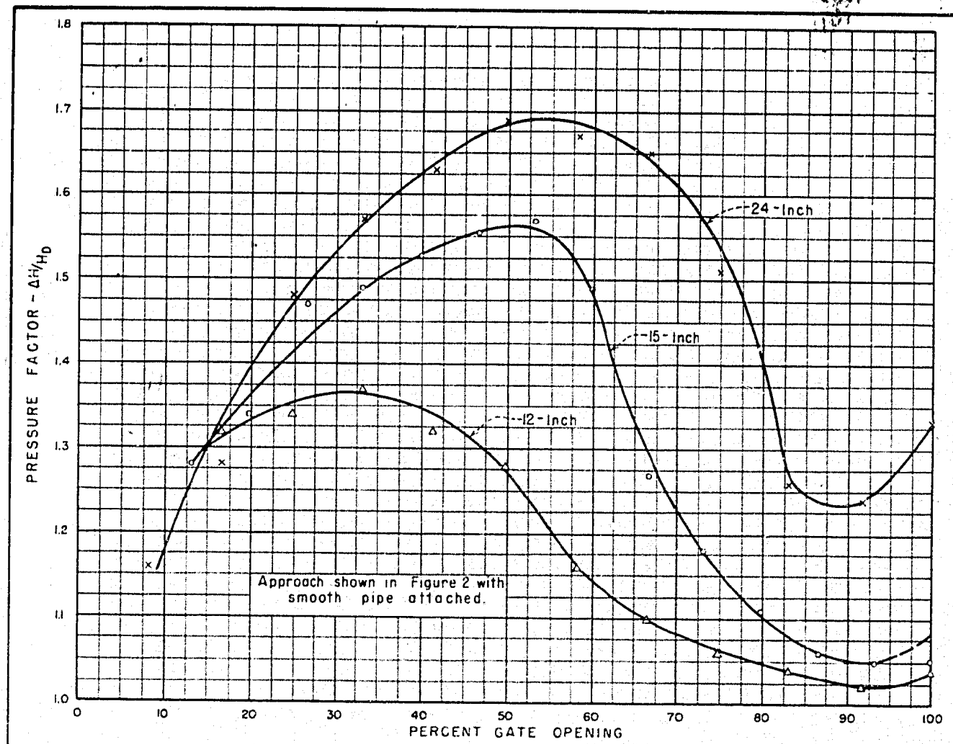
HARDESTY DIVISION
ARMCO DRAINAGE & METAL PRODUCTS, INC.
PROCEDURE 10

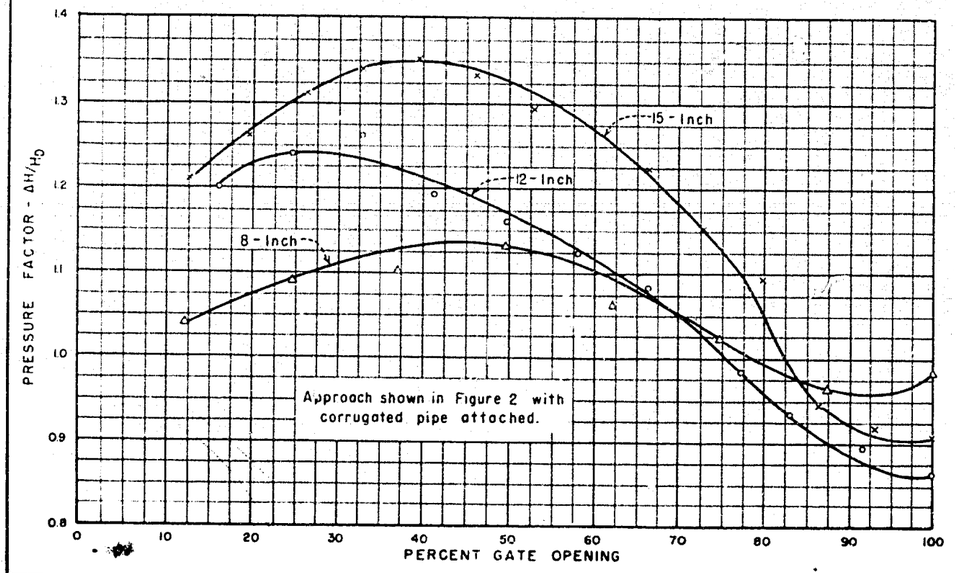
THE R. HARDESTY MFG. CO.
DENVER, COLO.

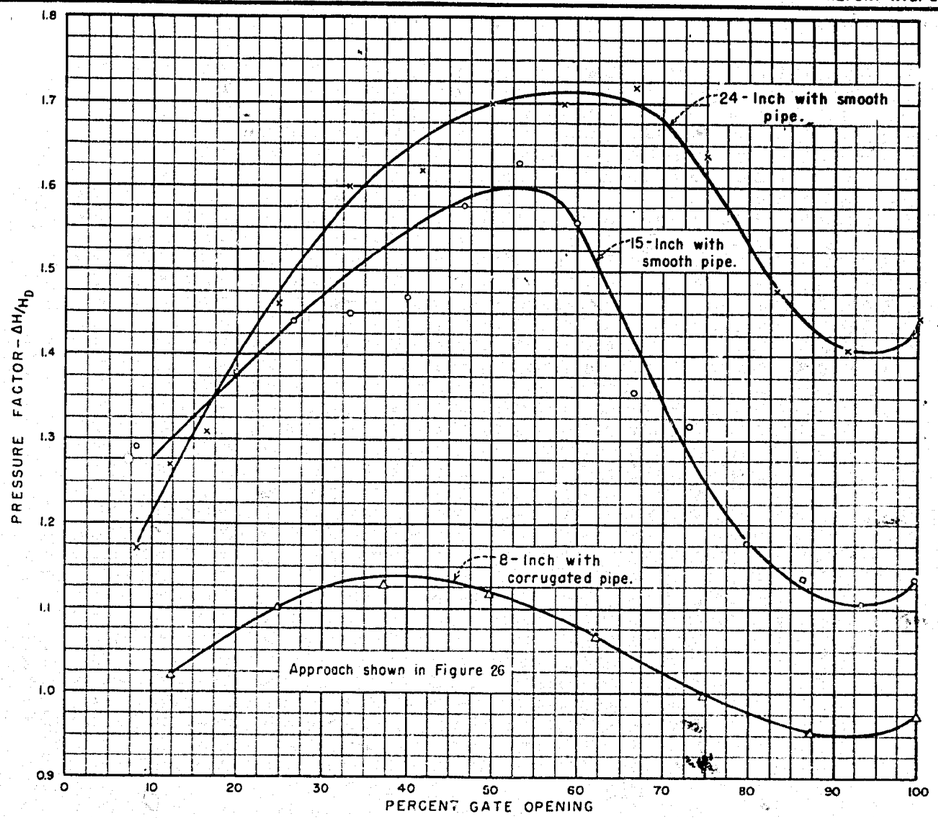
DETAILS OF SEAT, CALCO 101
8" To 24" DIA. CAST IRON

REVISED	DRAWN BY	TRACED BY	SCALE	ORDER NO.
	A.L.S.		NONE	
	CHECKED BY R.A.F.	APPROVED	DATE 9-[illegible]-43	[illegible]

REPORT HYD. 314 FIGURE 10





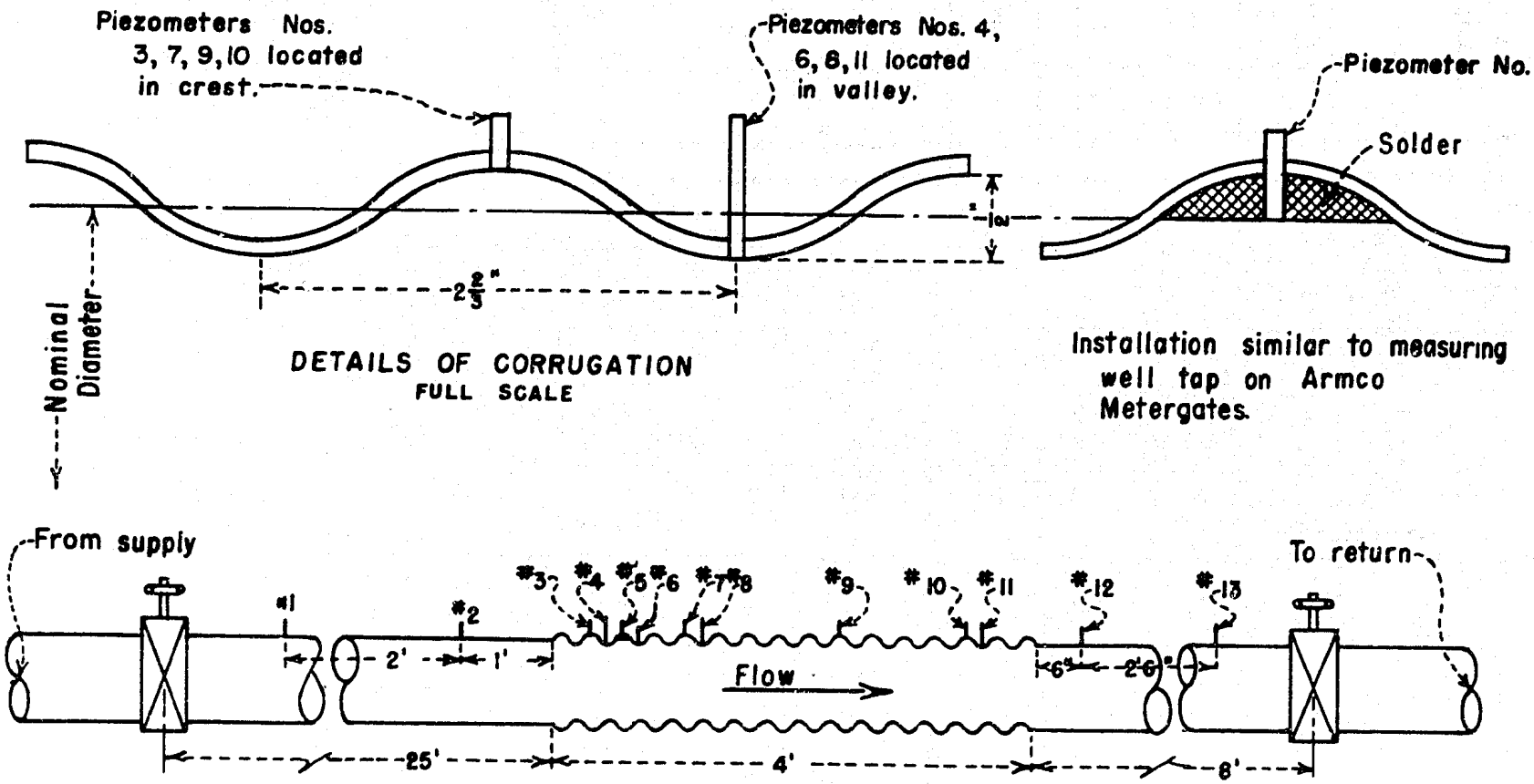


ΔH - Difference in W S in measuring wells.
H_D - Loss primarily due to gate. (See figure 2)

METERGATE STUDIES

8, 12, 15, 24 - INCH ARMCO METERGATES

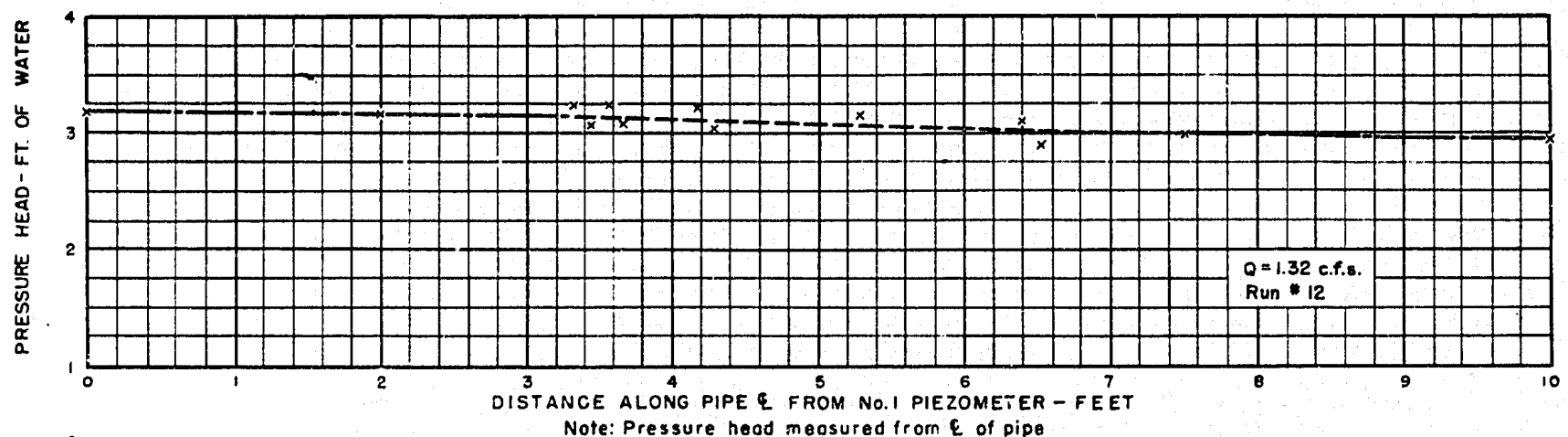
RELATIONSHIP BETWEEN EFFECTIVE HEAD (ΔH) AND GATE LOSS (H_D)

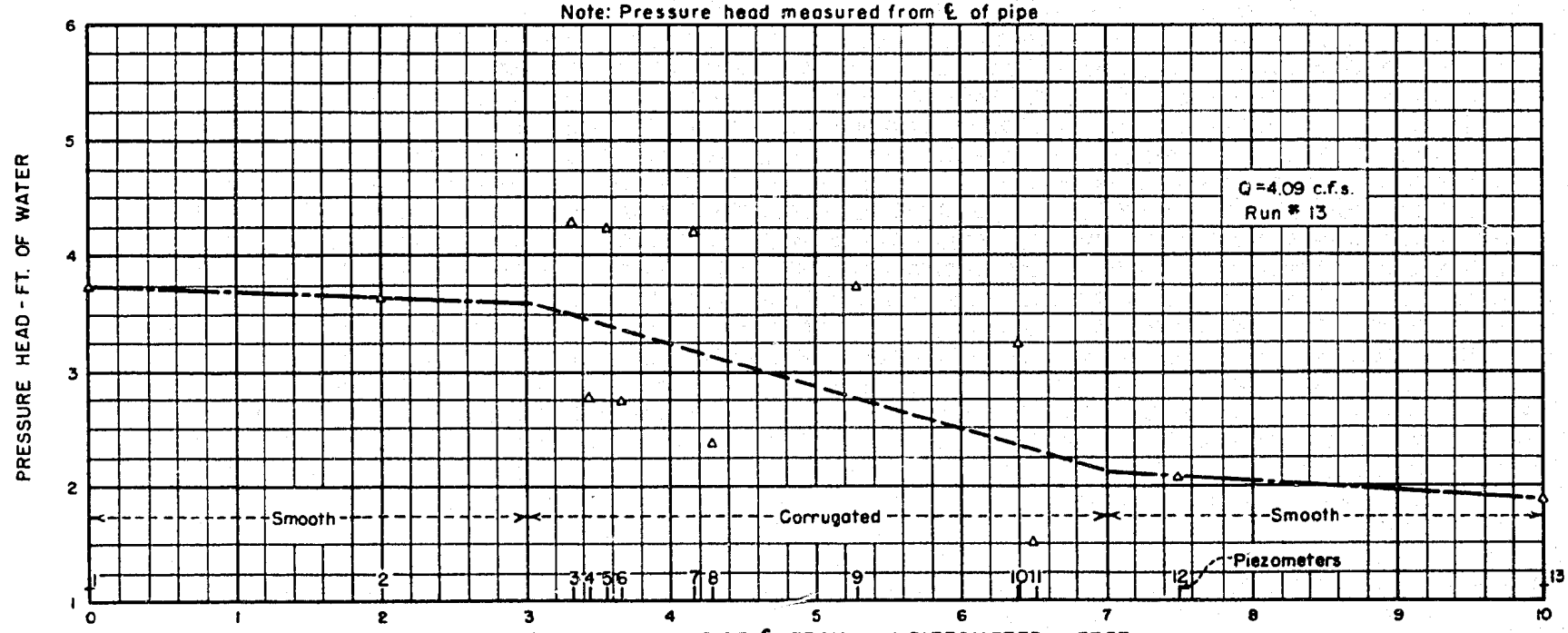


METERGATE STUDIES

LABORATORY INSTALLATION 8-INCH CORRUGATED PIPE TEST

FIGURE 12
REPORT HYD. 314





METERGATE STUDIES

RECORDED PRESSURE HEAD - CORRUGATED PIPE TEST

FIGURE 13
REPORT HYD. 314

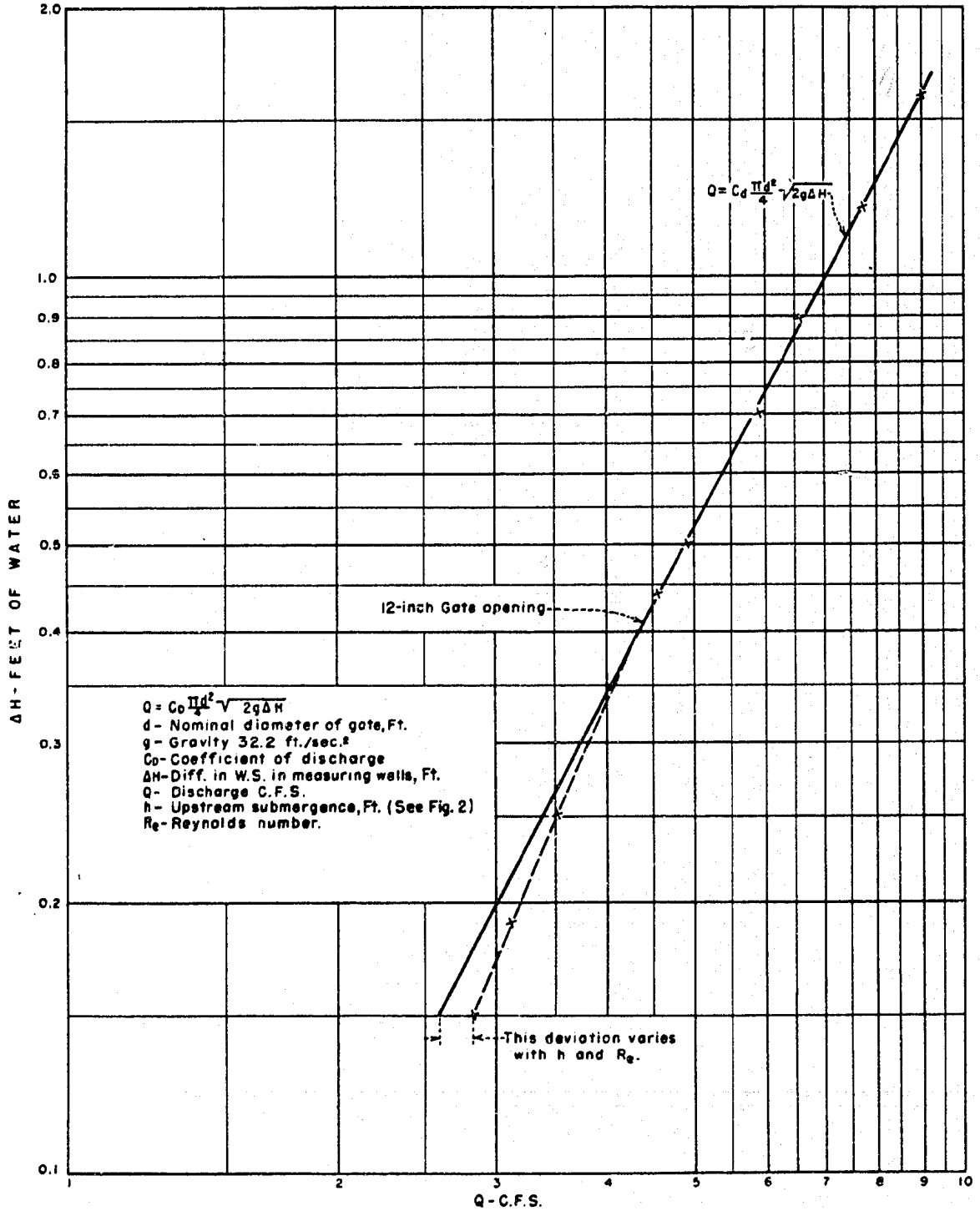
Table 1

STUDY OF PRESSURES IN 8-INCH CORRUGATED PIPE

Run No	Q cfs	Piezometers No 1	No 2	No 3	No 4	No 5	No 6	No 7	No 8	No 9	No 10	No 11	No 12	No 13
12	1.32	3.19	3.17	3.24	3.08	3.24	3.08	3.22	3.04	3.14	3.10	2.90	2.99	2.96
11	1.95	2.19	2.16	2.28	1.92	2.28	1.80	2.25	1.84	2.16	2.08	1.55	1.78	1.74
1	2.34	2.90	2.87	3.03	2.55	3.03	2.57	3.00	2.37	2.88	2.70	2.08	2.34	2.25
10	2.54	3.05	3.00	3.25	2.68	3.23	2.65	3.24	2.48	3.06	2.90	2.13	2.46	2.35
2	2.60	3.50	3.48	3.75	3.15	3.74	3.17	3.70	2.89	3.51	3.34	2.53	2.84	2.76
9	2.88	3.07	3.01	3.40	2.62	3.39	2.60	3.36	2.32	3.07	2.86	1.90	2.23	2.12
3	2.93	3.40	3.36	3.68	3.00	3.67	3.05	3.64	2.65	3.42	3.23	2.28	2.60	2.46
4	3.20	3.78	3.74	4.15	3.28	4.13	3.34	4.10	2.88	3.81	3.50	2.48	2.80	2.71
8	3.26	3.84	3.77	4.18	3.30	4.15	3.30	4.16	2.83	3.83	3.53	2.00	2.82	2.68
7	3.50	3.98	3.92	4.40	3.27	4.38	3.25	4.35	2.85	4.03	3.88	2.30	2.83	2.69
16	3.50	3.30	3.21	3.70	2.50	3.66	2.45	3.63	2.10	3.30	2.90	1.52	2.05	1.88
6	3.70	3.44	3.35	3.84	2.65	3.82	2.68	3.79	2.17	3.50	3.00	1.62	2.14	1.96
15	3.84	3.68	3.58	4.12	2.80	4.07	2.78	4.02	2.28	3.65	3.25	1.67	2.20	2.02
5	3.87	3.75	3.67	4.25	2.90	4.20	2.93	4.18	2.35	3.75	3.23	1.70	3.25	3.07
14	3.96	3.65	3.54	4.25	2.[illegible]	4.21	2.70	4.18	2.15	3.70	3.17	1.50	2.12	1.94
13	4.09	3.75	3.63	4.30	2.78	4.25	2.75	4.22	2.40	3.75	3.25	1.55	2.10	1.92

All piezometric pressures, in feet of water, are based on pipe center line. For location of piezometers, see Figure 12.

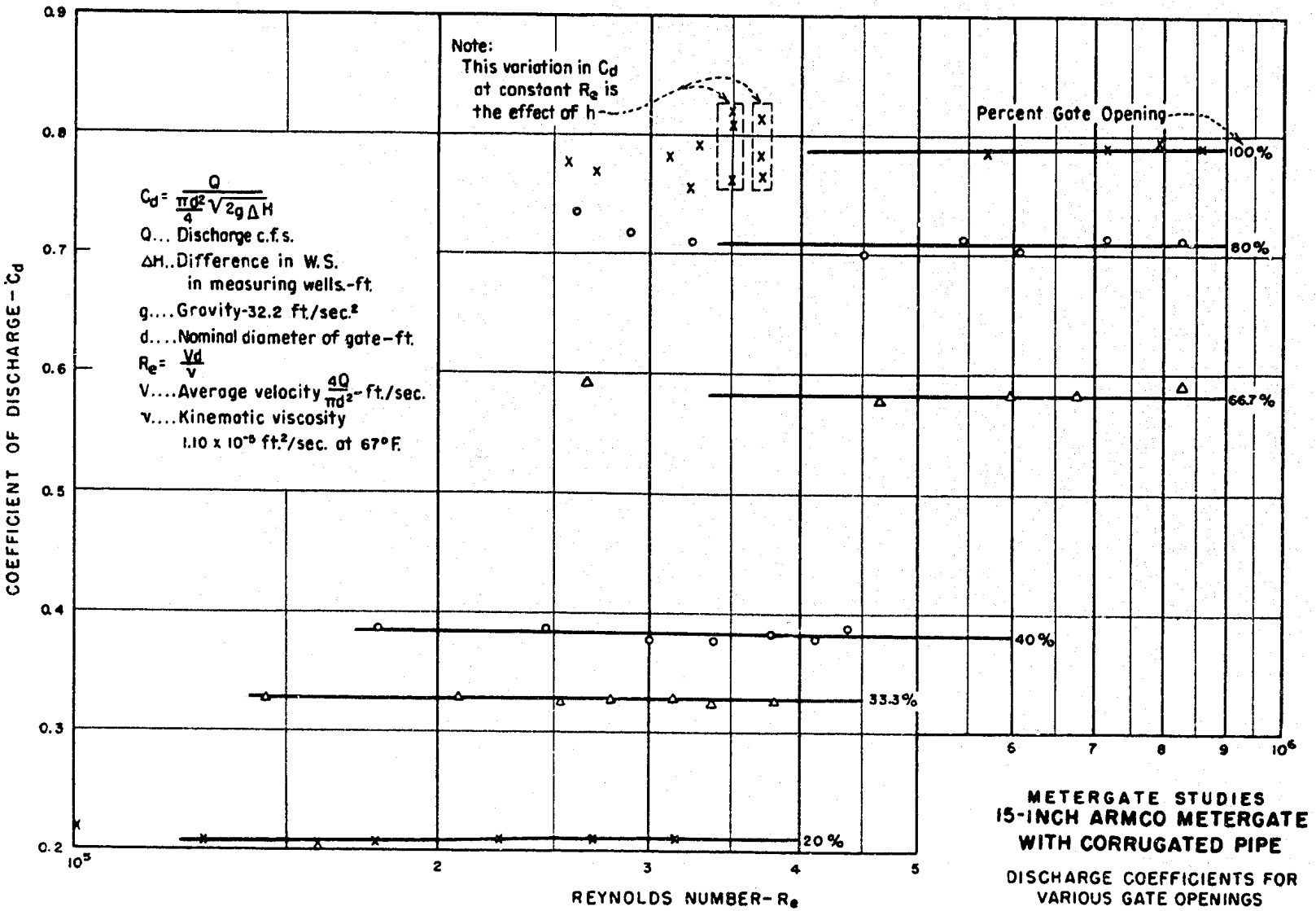
Figure 14



METERGATE STUDIES

15-INCH ARMCO METERGATE WITH CORRUGATED PIPE

DISCHARGE CURVE - 12-INCH GATE OPENING

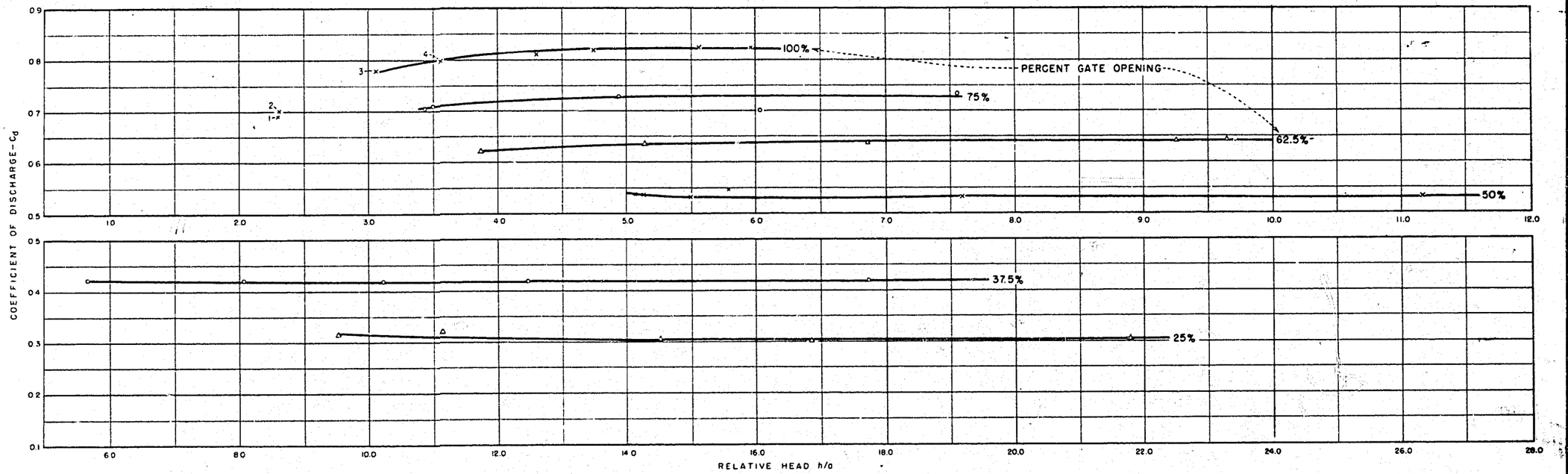


METERGATE STUDIES
15-INCH ARMCO METERGATE
WITH CORRUGATED PIPE

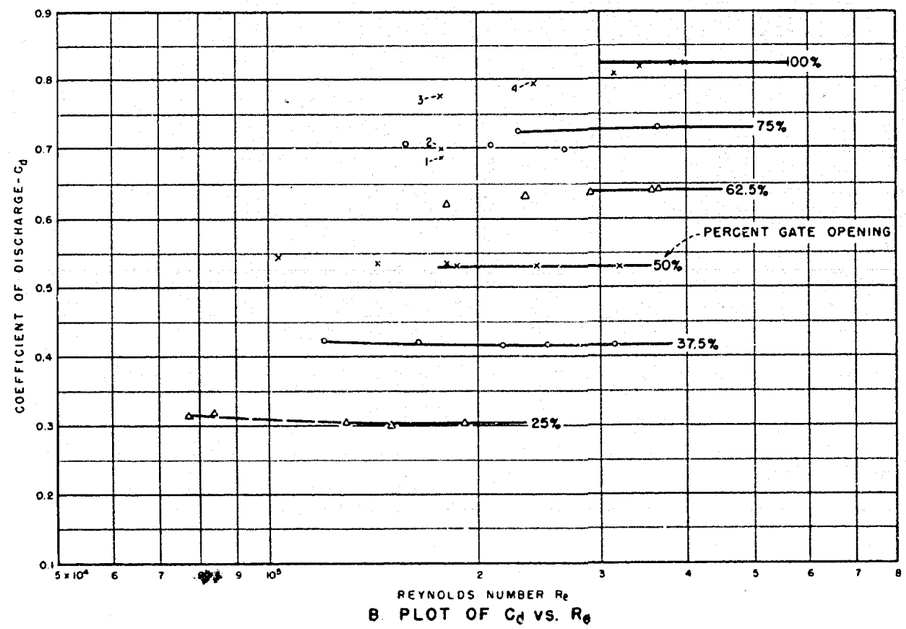
DISCHARGE COEFFICIENTS FOR
VARIOUS GATE OPENINGS

FIGURE 16
REPORT HYD. 314

FIGURE 17
REPORT HYD. 314



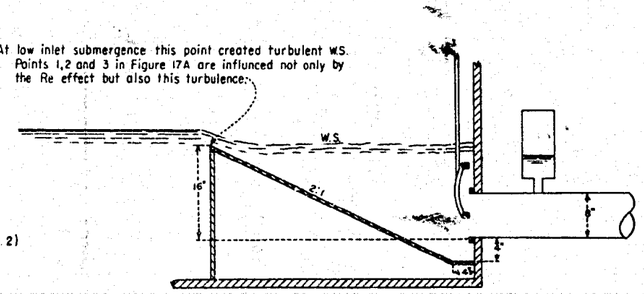
A. PLOT OF C_d vs. h/a



B. PLOT OF C_d vs. R_e

$Q = C_d \frac{\pi d^2}{4} \sqrt{2g\Delta H}$

Q = Discharge c.f.s.
C_d = Coefficient of discharge
d = Nominal diameter of gate, ft.
g = Gravity 32.2 ft./sec.^{2}
ΔH = Diff. in W.S. in measuring wells, ft.
h = Upstream submergence, ft. (See Fig. 2)
a = Gate opening, ft.
R_e = Reynolds Number

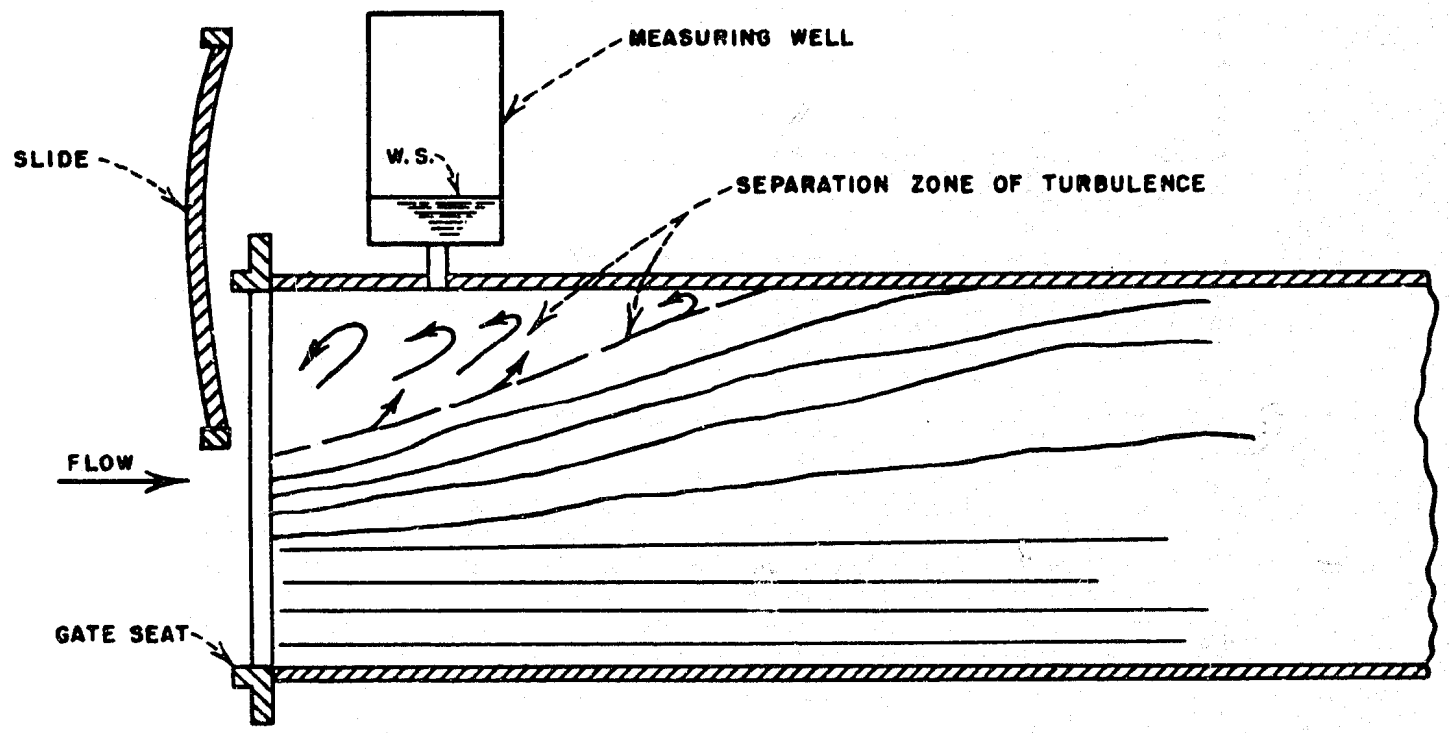


APPROACH USED IN TEST FOR RESULTS INDICATED ON ACCOMPANYING CHARTS

METERGATE STUDIES

C_d vs. h/a AND C_d vs. R_e FOR 8-INCH ARMCO METERGATE

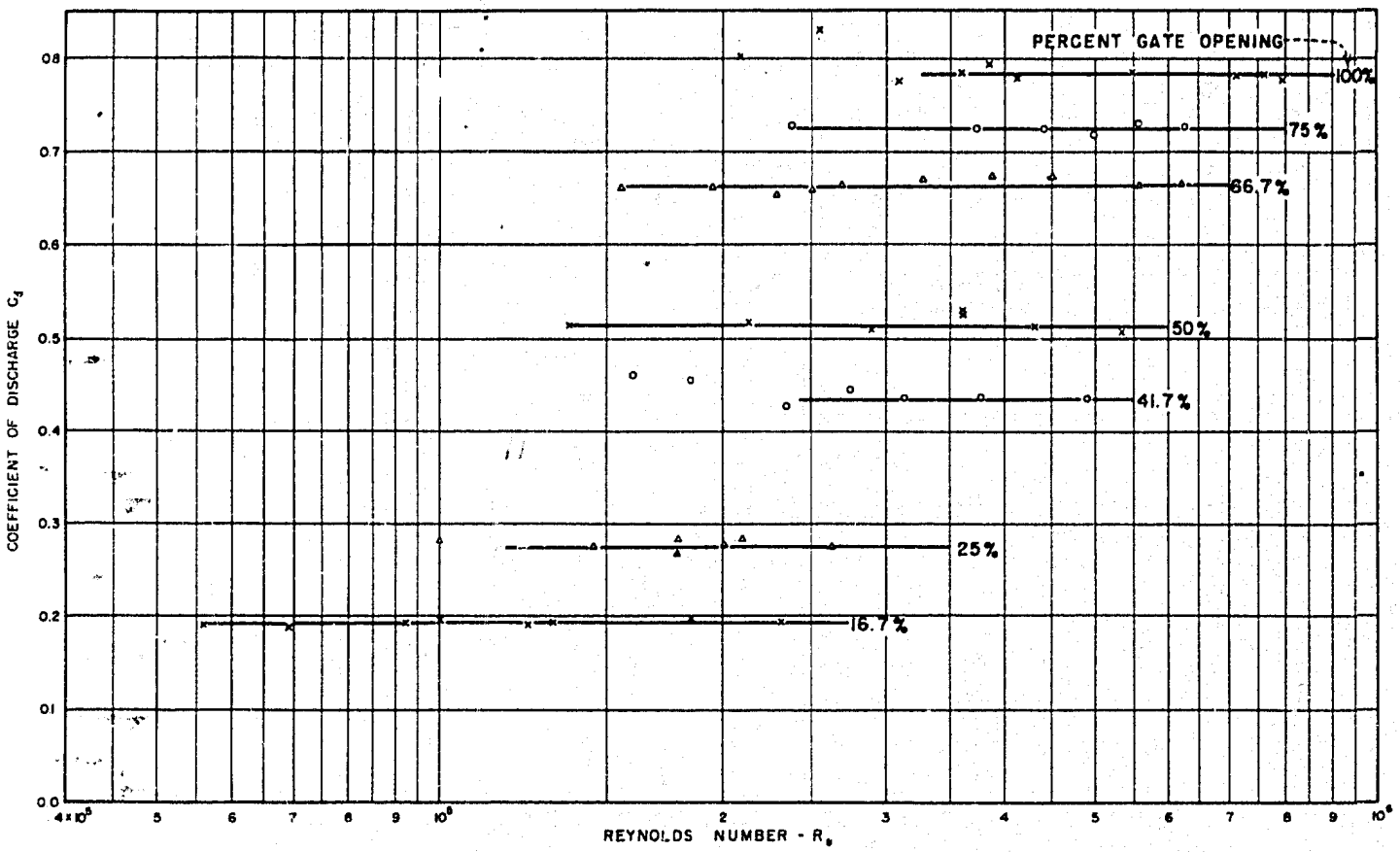
TESTED WITH CORRUGATED PIPE



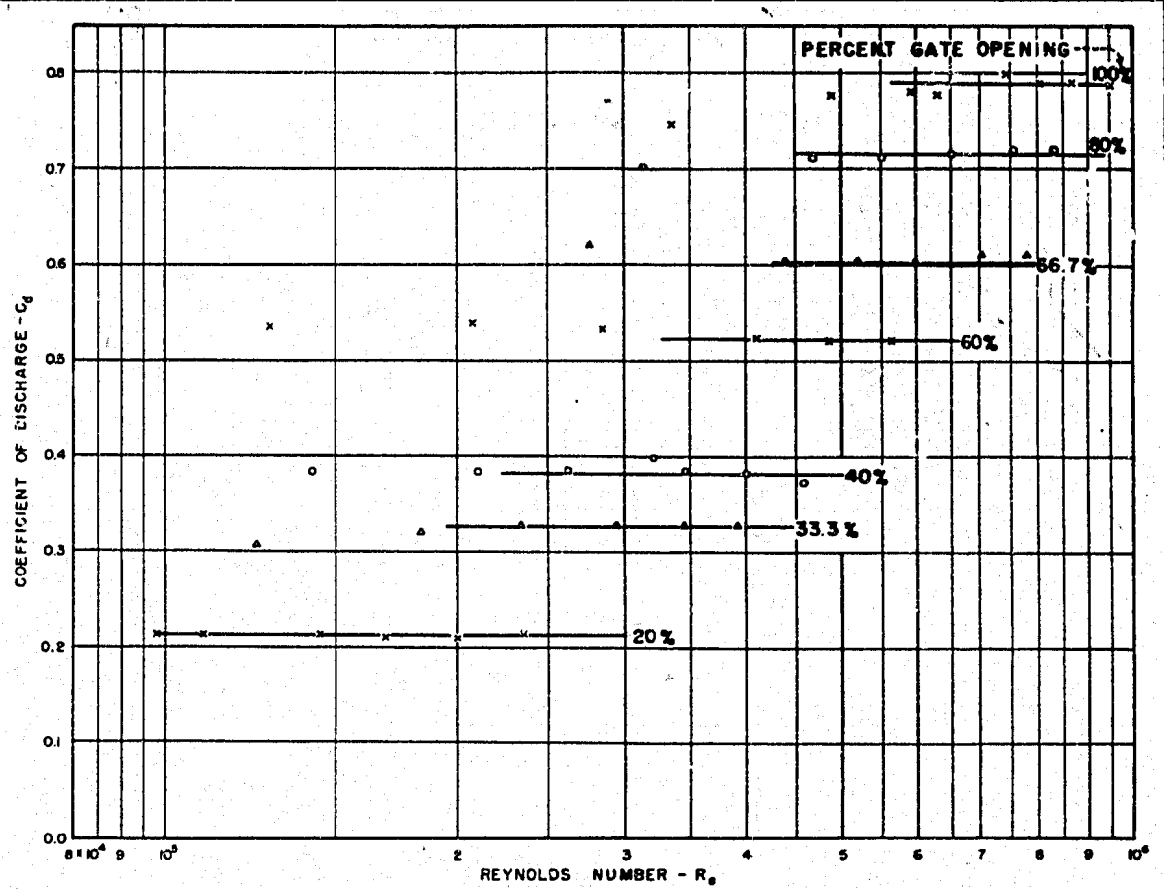
METERGATE STUDIES

SEPARATION ZONE DOWNSTREAM OF METERGATE

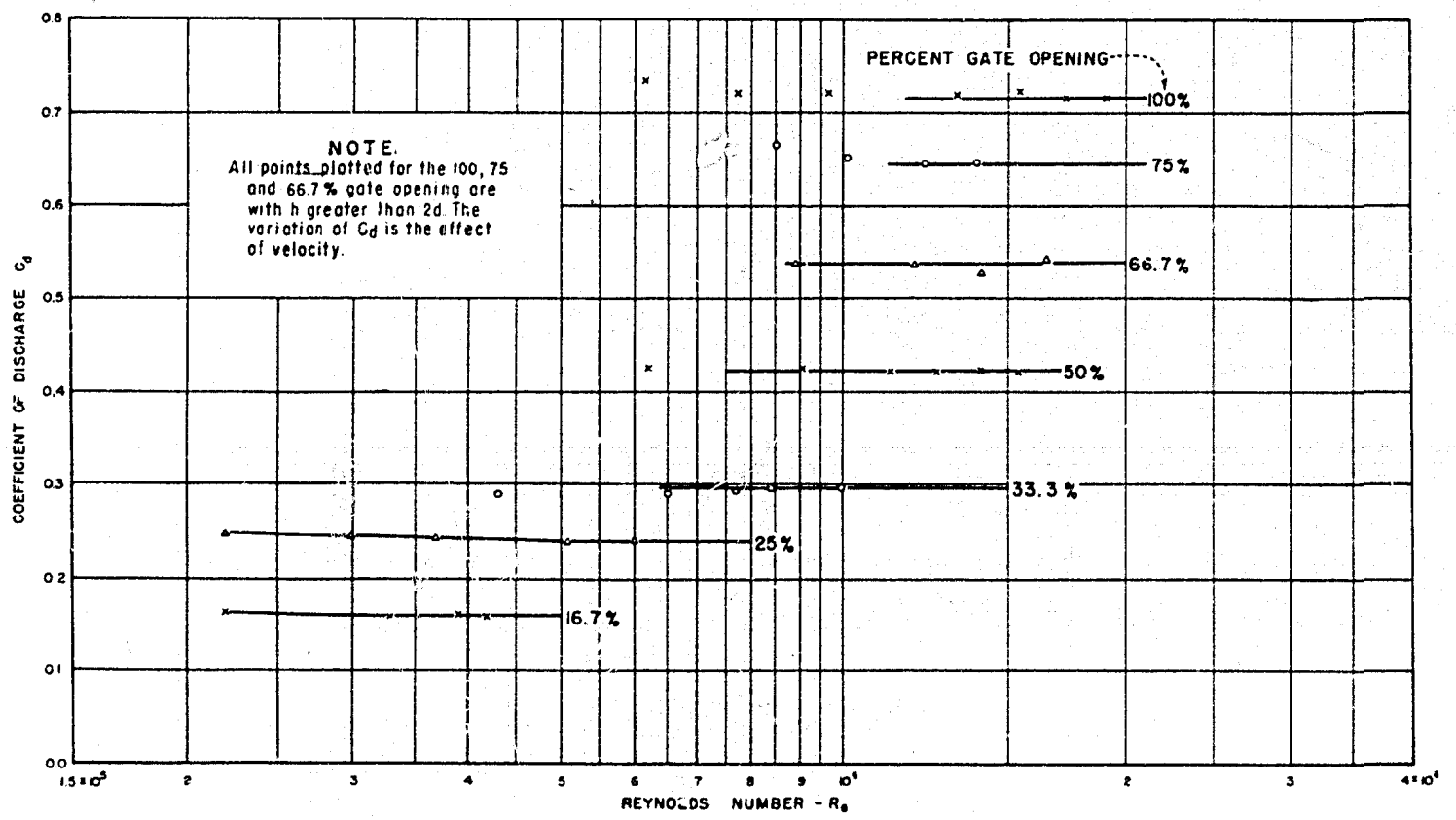
FIGURE 10
REPORT HYD. 314



A. 12-INCH METERGATE



C. 15-INCH METERGATE



B. 24-INCH METERGATE

$C_d = \frac{Q}{\frac{\pi d^2}{4}\sqrt{2g\Delta H}}$

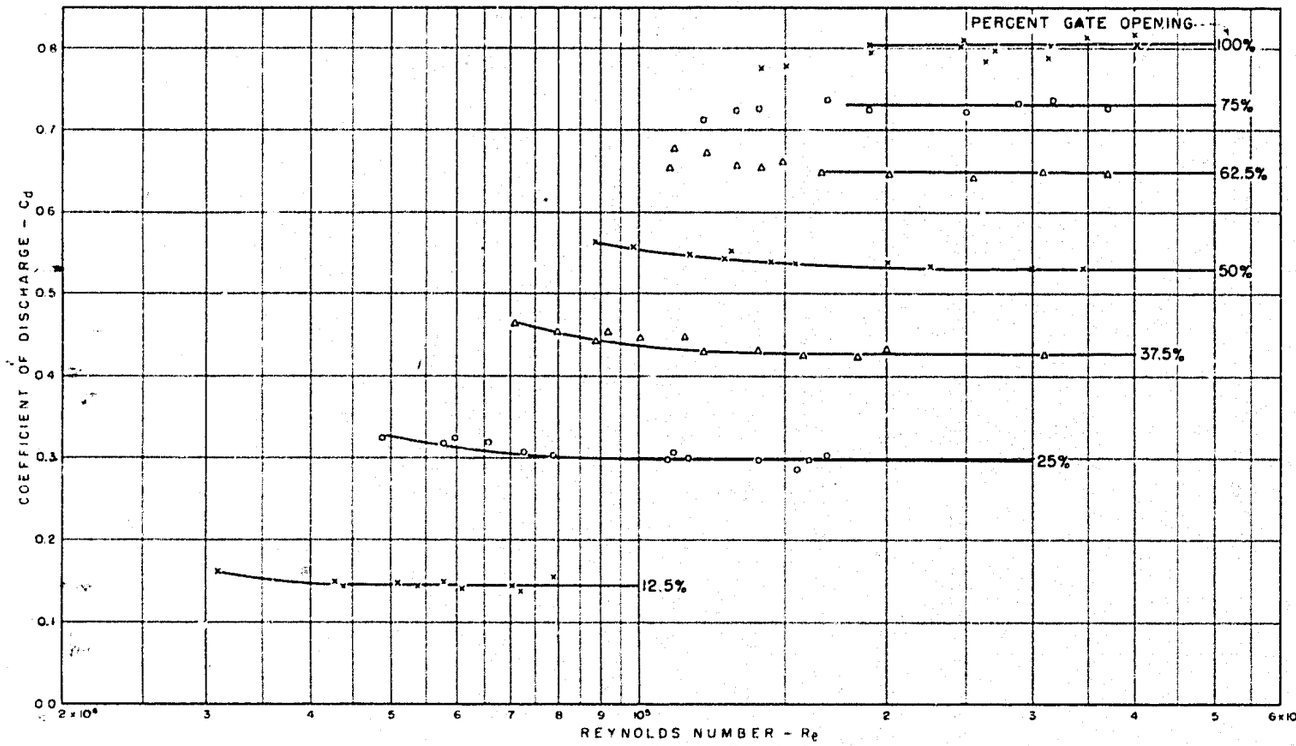
Q.... Discharge c.f.s.
ΔH... Difference in W.S. in measuring wells - Ft.
g.... gravity - 32.2 ft./sec.^{2}
d.... Nominal diameter of gate - ft.
R_e... Vd/ν
V.... Average velocity $\frac{4Q}{\pi d^2}$ - ft/sec.
ν.... Kinematic viscosity 1.10×10^{-5} ft.^{2}/sec. at 67°F.

METERGATE STUDIES

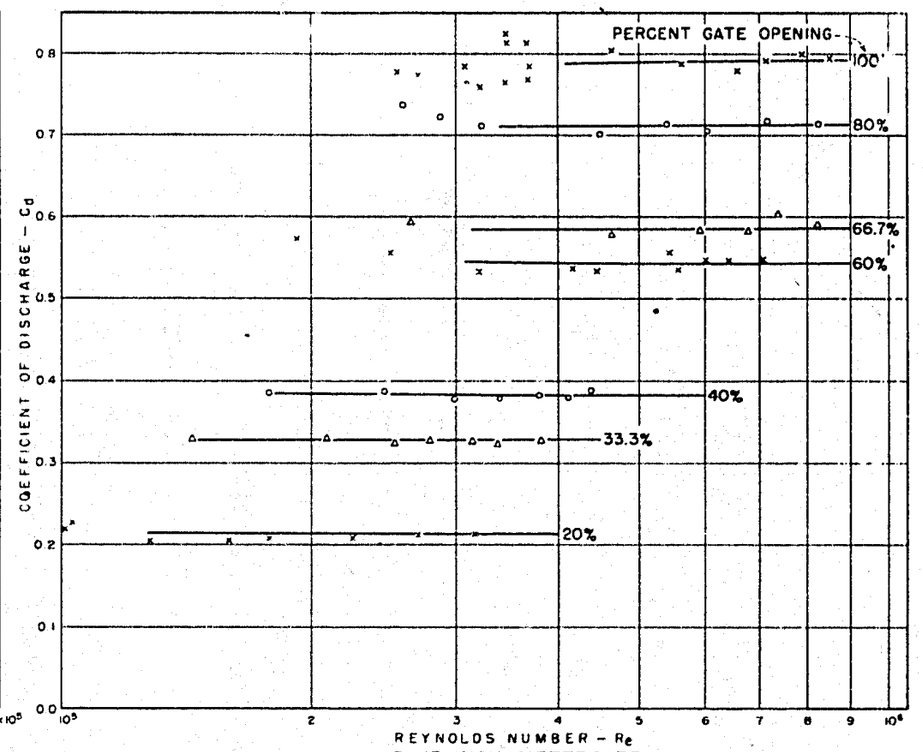
C_d vs. R_e FOR 12, 15 AND 24-INCH ARMCO METERGATES

TESTED WITH SMOOTH PIPE AND APPROACH SHOWN IN FIGURE 2

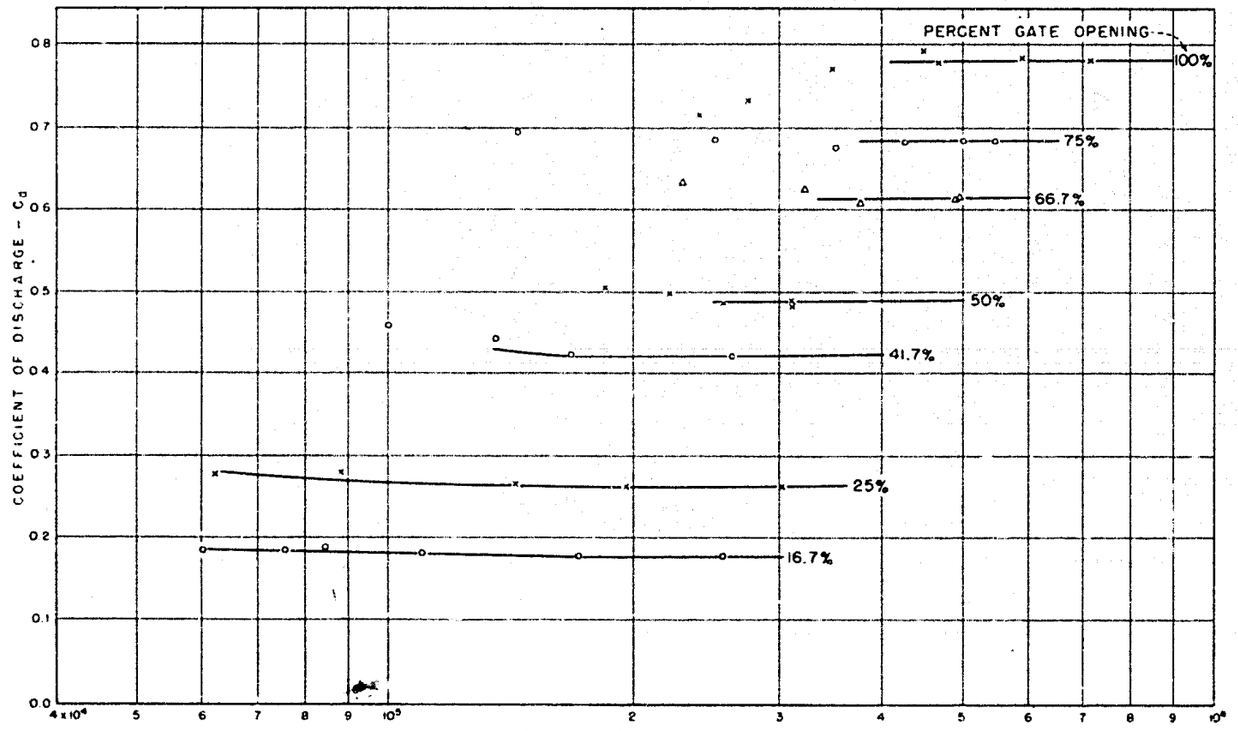
FIGURE 20
REPORT HYD. 314



A. 8-INCH METERGATE



B. 15-INCH METERGATE



B. 12-INCH METERGATE

NOTE

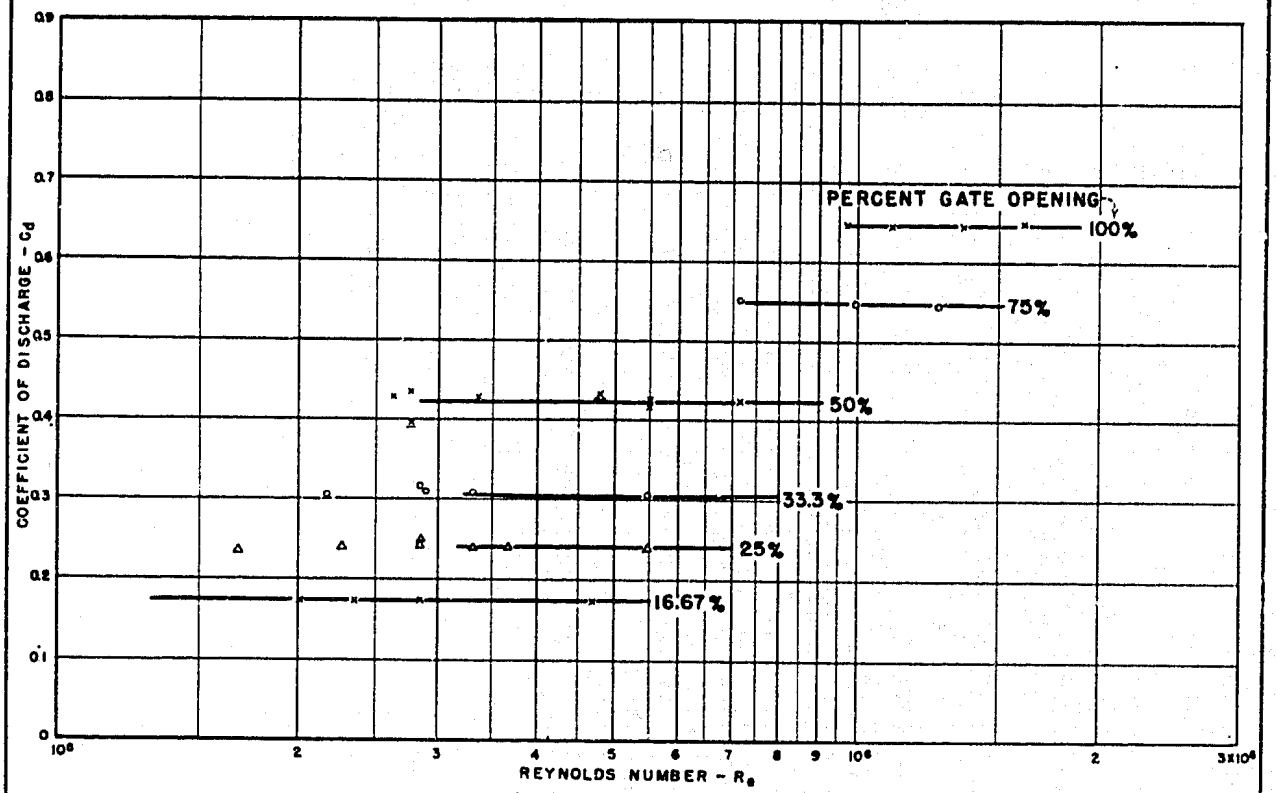
$C_d = \frac{Q}{\frac{\pi d^2}{4}\sqrt{2g\Delta H}}$

Q = Discharge c.f.s.
ΔH = Difference of W.S. in measuring wells - ft.
g = Gravity - 32.2 ft./sec.
d = Nominal diameter of gate - ft.
$R_e = \frac{Vd}{\nu}$
V = Average velocity $\frac{Q}{\pi d^2}$ - ft./sec.
ν = Kinematic viscosity 1.10×10^{-5} ft²/sec @ 67°F

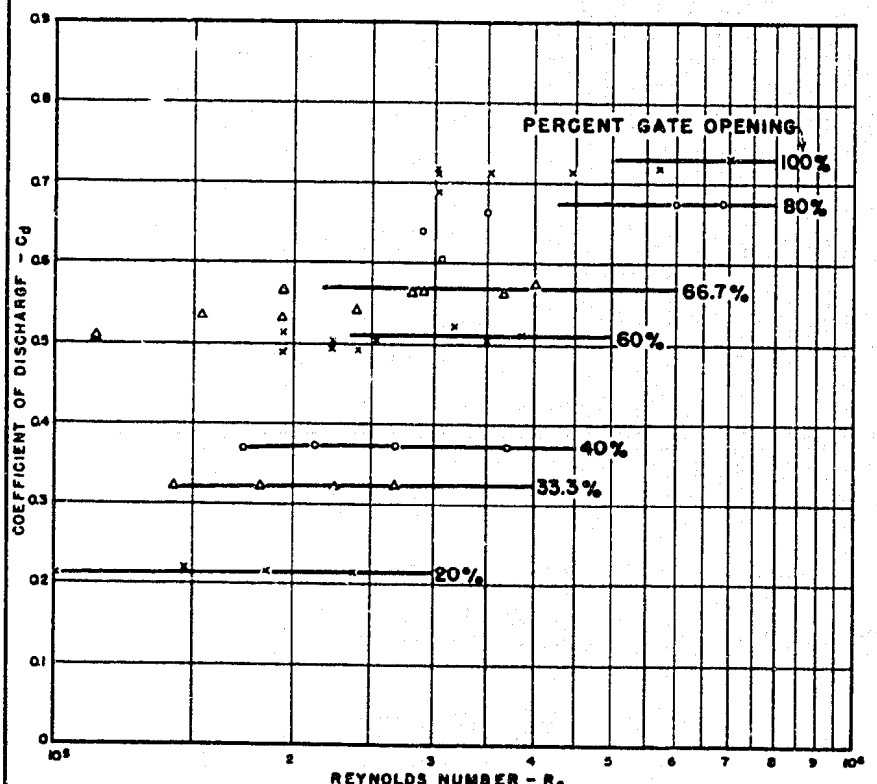
METERGATE STUDIES

C_d vs. R_e FOR 8, 12 AND 15-INCH ARMCO METERGATES

TESTED WITH CORRUGATED PIPE AND APPROACH SHOWN IN FIGURE 2



A. 24-INCH METERGATE



B. 15-INCH METERGATE

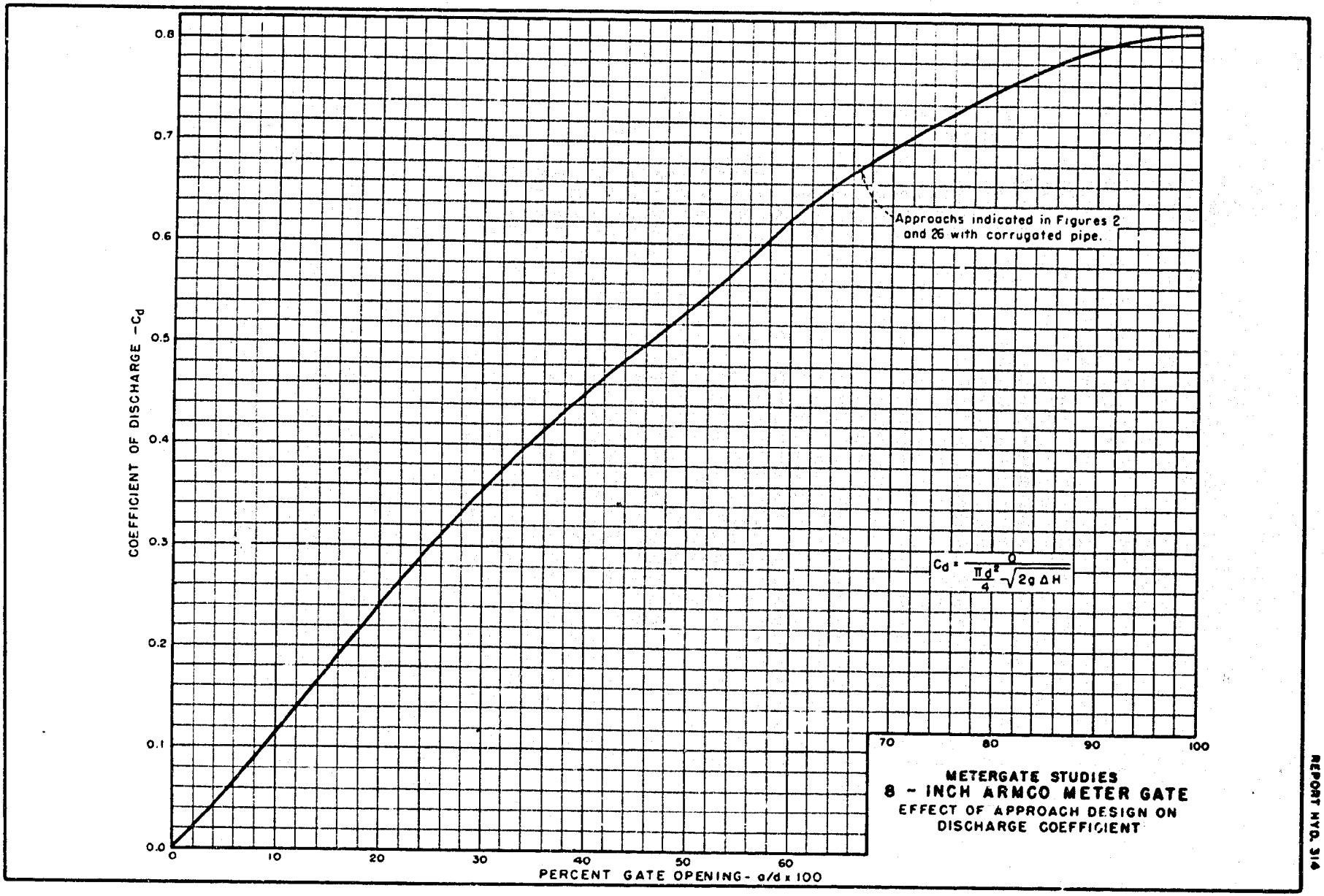
$$C_d = \frac{Q}{\frac{\pi d^2}{4}\sqrt{2g\Delta H}}$$

Q = Discharge c.f.s.
ΔH = Difference in W.S. in measuring wells - ft.
g = Gravity - 32.2 ft./sec.^{2}
d = Nominal diameter of gate - ft.
$R_e = Vd/\nu$
V = Average velocity $\frac{4Q}{\pi d^2}$ - ft./sec.
ν = Kinematic viscosity 1.10×10^{-5} ft.^{2}/sec. at 67°F.

METERGATE STUDIES

C_d vs. R_e FOR 15 AND 24-INCH ARMCO METERGATES

TESTED WITH SMOOTH PIPE AND APPROACH SHOWN IN FIGURE 26



METERGATE STUDIES
8 - INCH ARMCO METER GATE
EFFECT OF APPROACH DESIGN ON DISCHARGE COEFFICIENT

FIGURE 22
REPORT HYD. 314

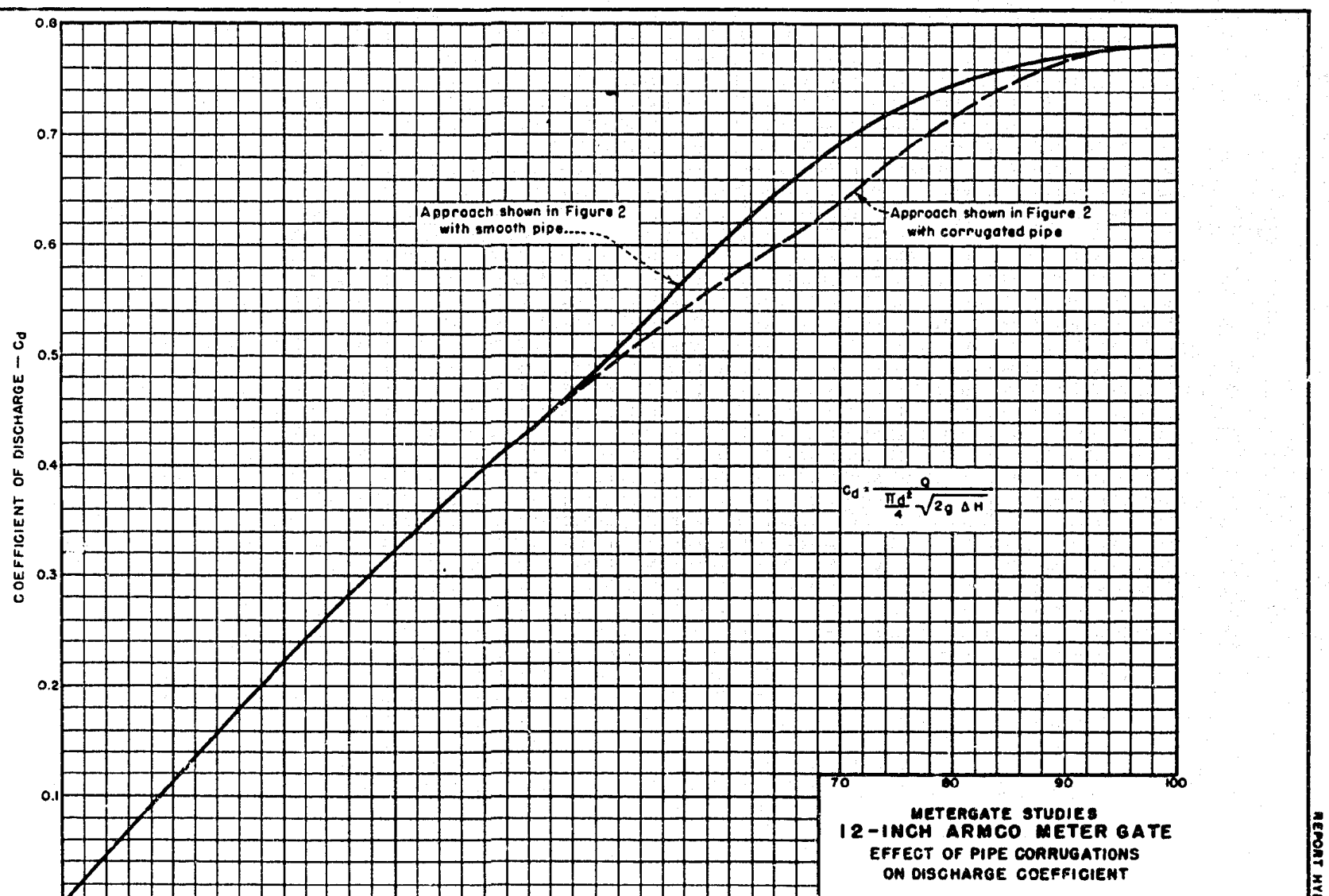
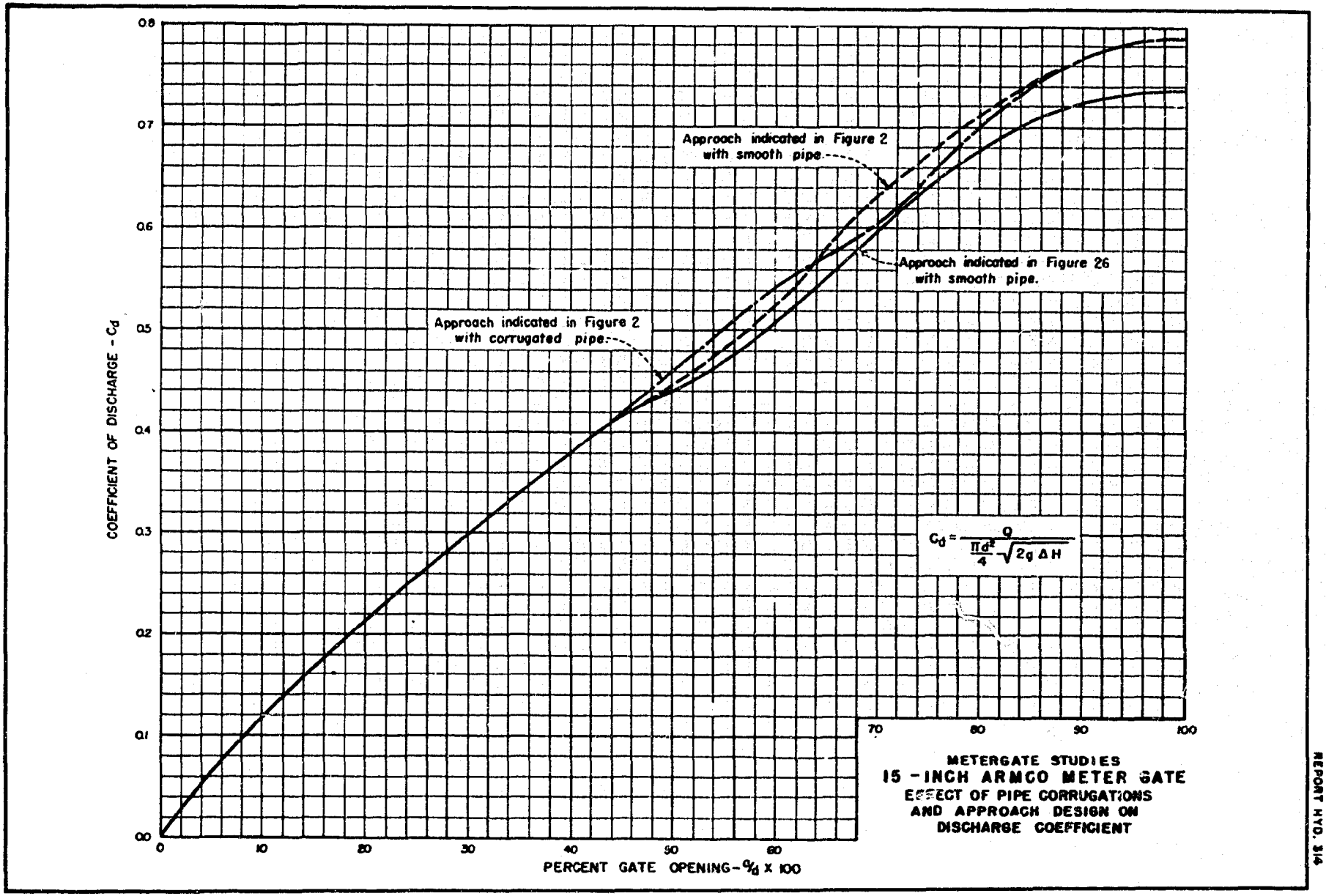
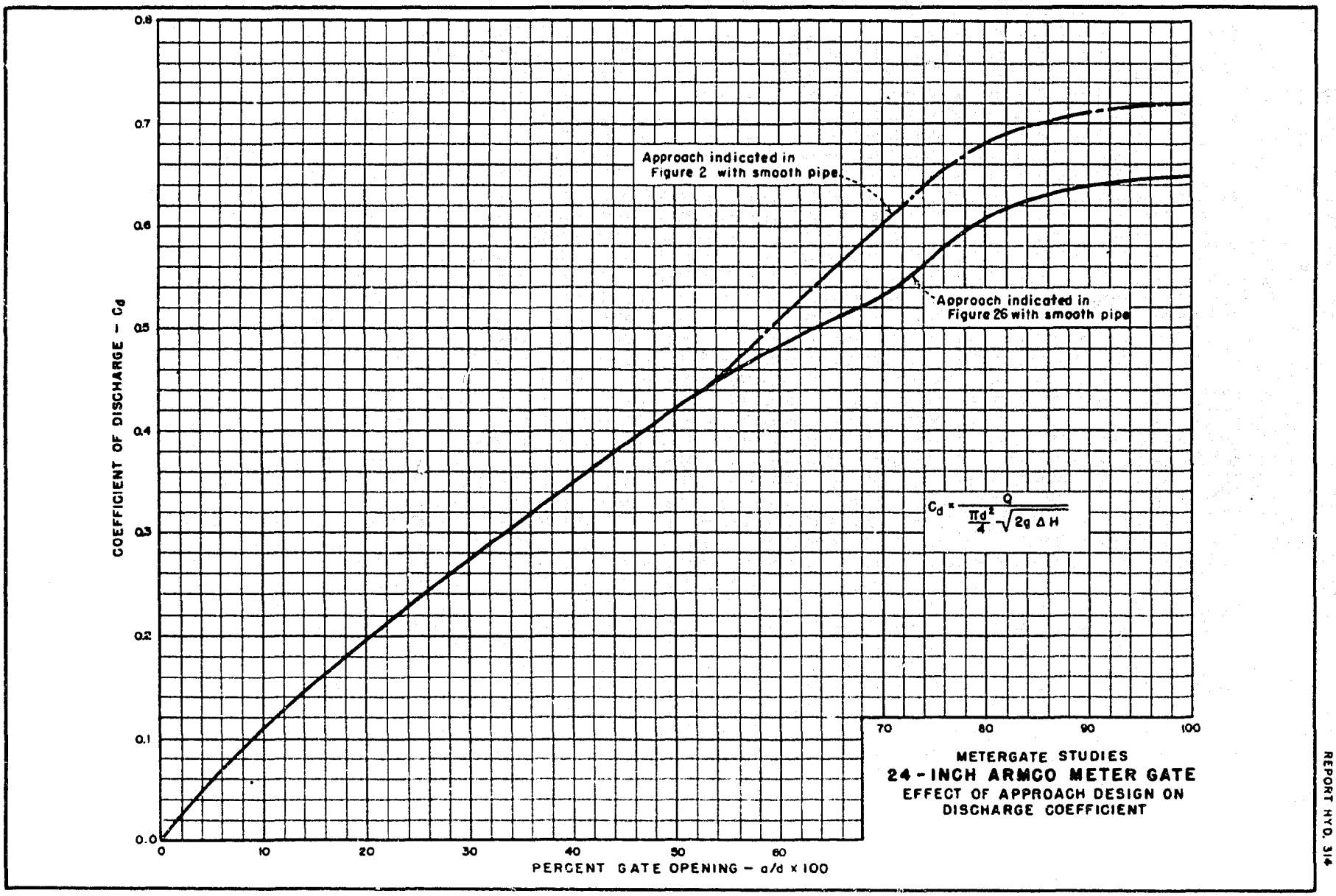


FIGURE 23
REPORT HYD. 314



METERGATE STUDIES
15 - INCH ARMCO METER GATE
EFFECT OF PIPE CORRUGATIONS
AND APPROACH DESIGN ON
DISCHARGE COEFFICIENT

FIGURE 24
REPORT HYD. 314

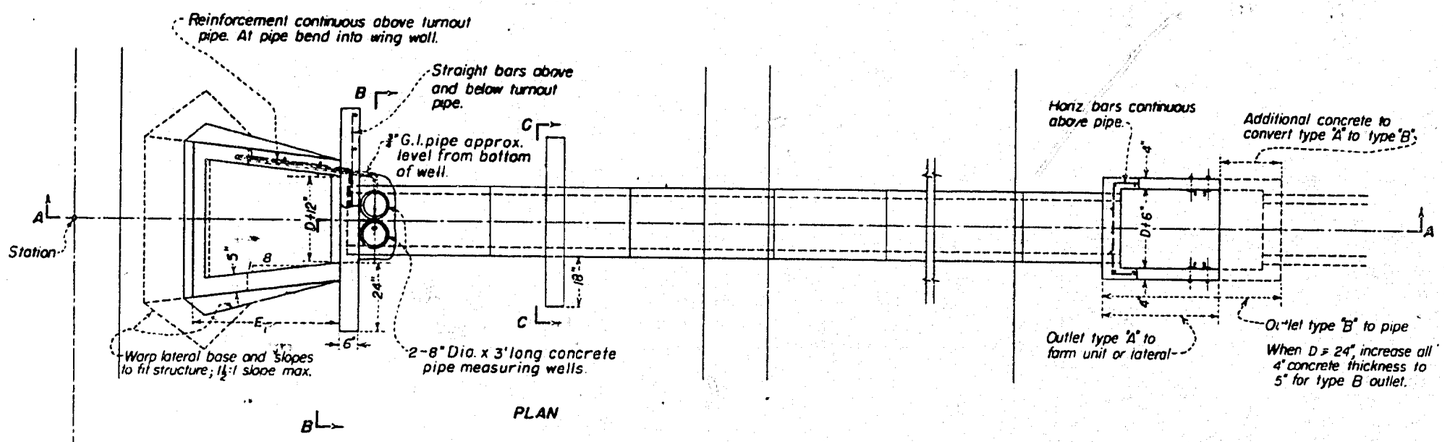


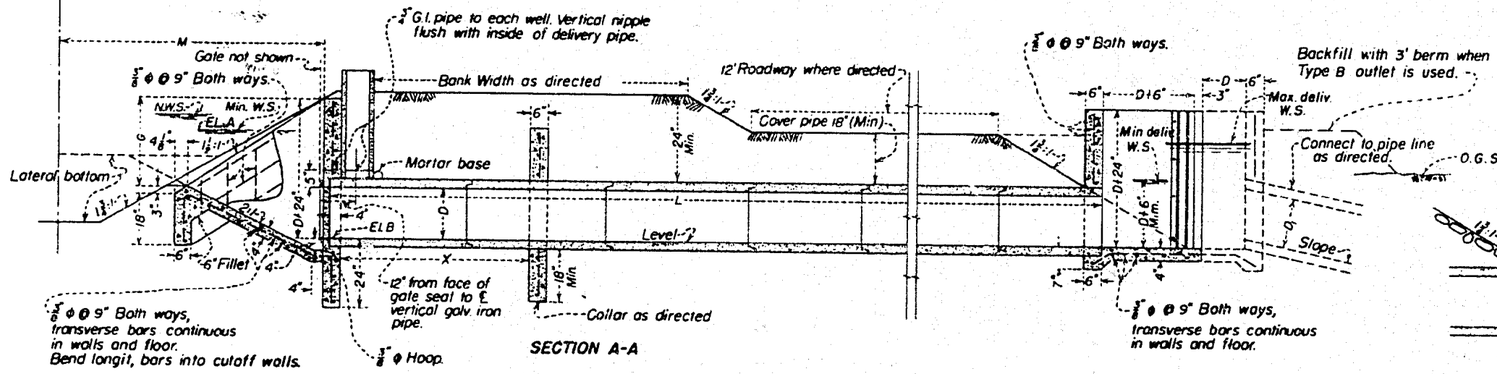
METERGATE STUDIES

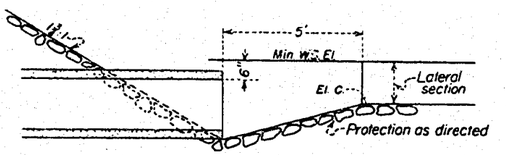
24 - INCH ARMCO METER GATE

EFFECT OF APPROACH DESIGN ON DISCHARGE COEFFICIENT

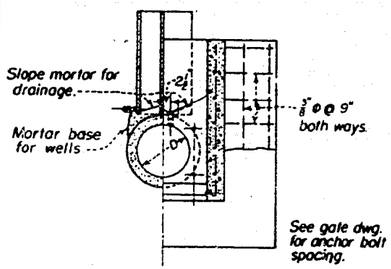
FIGURE 25
REPORT HYD. 314



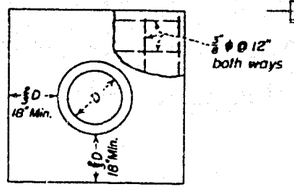




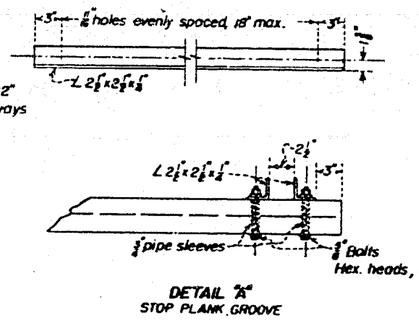
OUTLET TYPE "C"
TO LATERAL OR WEIR POOL ONLY



SECTION B-B



SECTION C-C



DETAIL "A"
STOP PLANK GROOVE

TABLE OF LOCATIONS, TYPES, DIMENSIONS & ELEVATIONS

LATERAL	STATION	T.O. to Lateral or F.U. No.	Rt. or Lt.	M	ELEVATIONS A	ELEVATIONS B	Outlet Type	PIPE D	PIPE L	Collar Dist. X	DELIVERY Max. Q	DELIVERY Max. Dist. W.S. El.	TYPE B D	TYPE B Slope	TYPE C El. C
EL 6	1+43.73		Rt.	*	1308.70	1305.95	A	18"	80'		4	1308.36	—	—	—
EL 6.9	15+75.00	EL6.9A	Rt.	12.92'	1305.41	1303.83	A (2)	21"	12'		5	1306.09	—	—	—
EL 6.9	42+22.50	EL6.9B	Rt.	12.43	1306.41	1303.99	A (2)	18"	12'		5	1305.99	—	—	—
EL 6.9	62+90	EL6.9D	Rt.	9.18(1)	1306.31	1304.32	C (2)	15"	9'		5	1302.82	—	—	1300.99
EL 6.9	74+00		Rt.	10.72	1305.58	1303.30	A	18"	18'		4	1305.30	—	—	—
EL 6.9	104+50		Rt.	11.80	1305.58	1302.81	A	24"	18"		6	1305.31	—	—	—
EL 6.9	117+86	EL6.9E	Rt.	10.53	1304.57	1301.82	C	24"	18'		10	1304.15	—	—	1302.84
EL 6.9	135+39.35	EL6.9EE	Rt.	10.95	1304.57	1302.17	A	18"	15'		6	1304.17	—	—	—
EL 6.9	152+70.53	EL6.9F	Lt.	11.79	1304.57	1302.30	A	18"	12'		4	1304.30	—	—	—
EL 6.9	180+56		Lt.	*	1293.74	1289.74	A	18"	6'		6	1293.36	—	—	—
EL 6.9	180+56		℄	*	1293.74	1289.74	B	30"	6'		24	1292.93	30"	.265	—
EL 6.9	210+70.82		Lt.	*	1285.25	1282.75	A	18"	27'		6	1284.79	—	—	—
EL 6.9E	14+35.55		℄	*	1302.19	1299.69	A	18"	6'		5	1301.93	—	—	—
EL 6.9E	21+75.8		Lt.	*	1297.43	1294.43	A	24"	6'		4	1297.16	—	—	—
EL 6.9H	26+32.47		Rt.	*	1287.80	1285.55	A	18"	21'		5	1287.50	—	—	—
EL 6.9H	35+69.81		Lt.	*	1283.56	1281.29	A	18"	6'		5	1283.28	—	—	—
EL 6.9H	57+50		Rt.	*	1280.50	1278.00	A	18"	6'		2	1280.24	—	—	—
EL 6.9H	57+50		Lt.	*	1280.50	1278.00	A	18"	6'		3	1280.24	—	—	—
EL 6.9H	94+15.6	EL6.9H1	Lt.	*	1273.00	1269.00	C	21"	27'		13	1271.97	—	—	1270.37
EL 6.9H	94+15.6		Rt.	*	1273.00	1270.74	A	18"	6'		4	1272.74	—	—	—
EL 6.9H	106+81.07		℄	*	1266.74	1263.74	A	15"	15'		4	1266.41	—	—	—
EL 6.9H	122+61.47		Rt.	*	1262.83	1260.33	A	18"	18'		4	1262.55	—	—	—
EL 6.9H	137+55.69		℄	*	1255.80	1253.30	A	18"	6'		4	1255.54	—	—	—
EL 6.9H1	14+02.90		Rt.	*	1268.67	1266.50	A	15"	6'		4	1268.37	—	—	—
EL 6.9H1	25+77.48		℄	*	1266.31	1263.31	A	15"	12'		4	1266.99	—	—	—
EL 6.9H1	34+77.48		Lt.	*	1265.68	1263.62	A	15"	12'		4	1265.37	—	—	—
EL 6.9H1	46+33.38		Rt.	*	1263.82	1261.07	A (2)	18"	6'		4	1263.39	—	—	—

* T.O. from division box. See Division Box drawing for gate data. (1) Omit Measuring Wells.
(2) Outlet Str. to be placed at end of Road Crossing.

TABLE OF DIMENSIONS AND ESTIMATED QUANTITIES*

D	TURNOUT STRUCTURE G	TURNOUT STRUCTURE E	TURNOUT STRUCTURE Conc. Cu. Yds.	TURNOUT STRUCTURE Reinf. Steel Lbs.	GATE Frame Ht.	GATE Wt.	OUTLET TYPE A Conc. Cu. Yds.	OUTLET TYPE A Reinf. Steel Lbs.	OUTLET TYPE B Misc. Metal Lbs.	OUTLET TYPE B Conc. Cu. Yds.	OUTLET TYPE B Reinf. Steel Lbs.
12"	2'-0"	3'-4"	0.9	59	5	80	0.3	20	55	0.5	34
15"	2'-1½"	3'-6½"	1.0	65	5	90	0.4	23	59	0.6	41
18"	2'-3"	3'-9½"	1.1	72	5	149	0.4	28	63	0.8	48
21"	2'-5"	3'-11½"	1.2	78	5	175	0.5	32	69	0.9	57
24"	2'-7"	4'-2"	1.3	86	5	200	0.6	35	74	1.0	65
30"	2'-10½"	4'-7½"	1.6	102	5	365	0.7	46	83	1.3	86

* Exclusive of collars

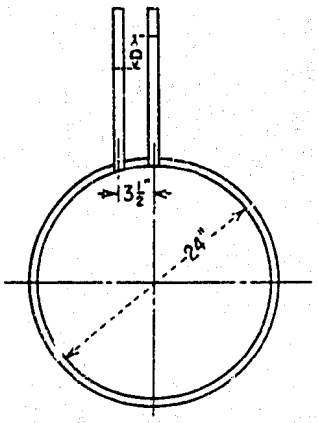
NOTES

All reinforcement shall be placed in the center of slab unless otherwise shown.
All exposed bolts to be galvanized.
Turnout shall be connected to road crossing at "L" distance from headwall where directed.
Number and location of collars to be as directed.
This structure limited to D of 30".
Measuring wells to be omitted where directed.
Gate anchor bolts to be set in position before concrete is placed.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
COLUMBIA BASIN PROJECT—WASHINGTON
EAST LOW CANAL LATERALS — AREA E-1
PIPE TURNOUTS WITH MEASURING WELLS
TYPE 2 - EL.6 TO EL.6.9 H1

DRAWN J.C.P-R&M. SUBMITTED O.J. Davidson
TRACED H.E.M. RECOMMENDED
CHECKED APPROVED
CHIEF ENGINEER

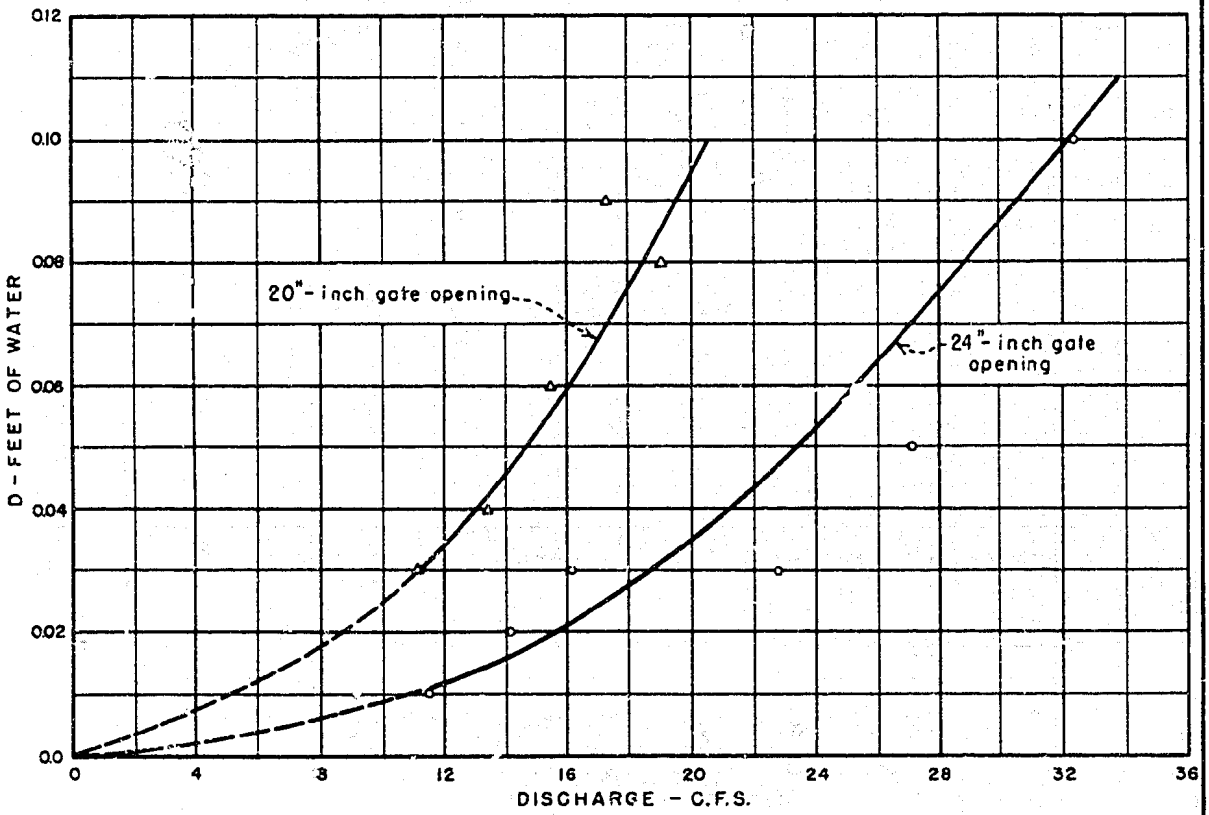
222-P-8034 | EPHRATA, WASHINGTON SEPT 30, 1948 SHEET 1 OF 5 | 222-D-14571



Percent error in $\Delta H = \frac{D}{\Delta H} \times 100$

Gate opening.	20"	24"
Average % error in ΔH.	7.5%	3%
Average % error in discharge.	2.8%	1.7%

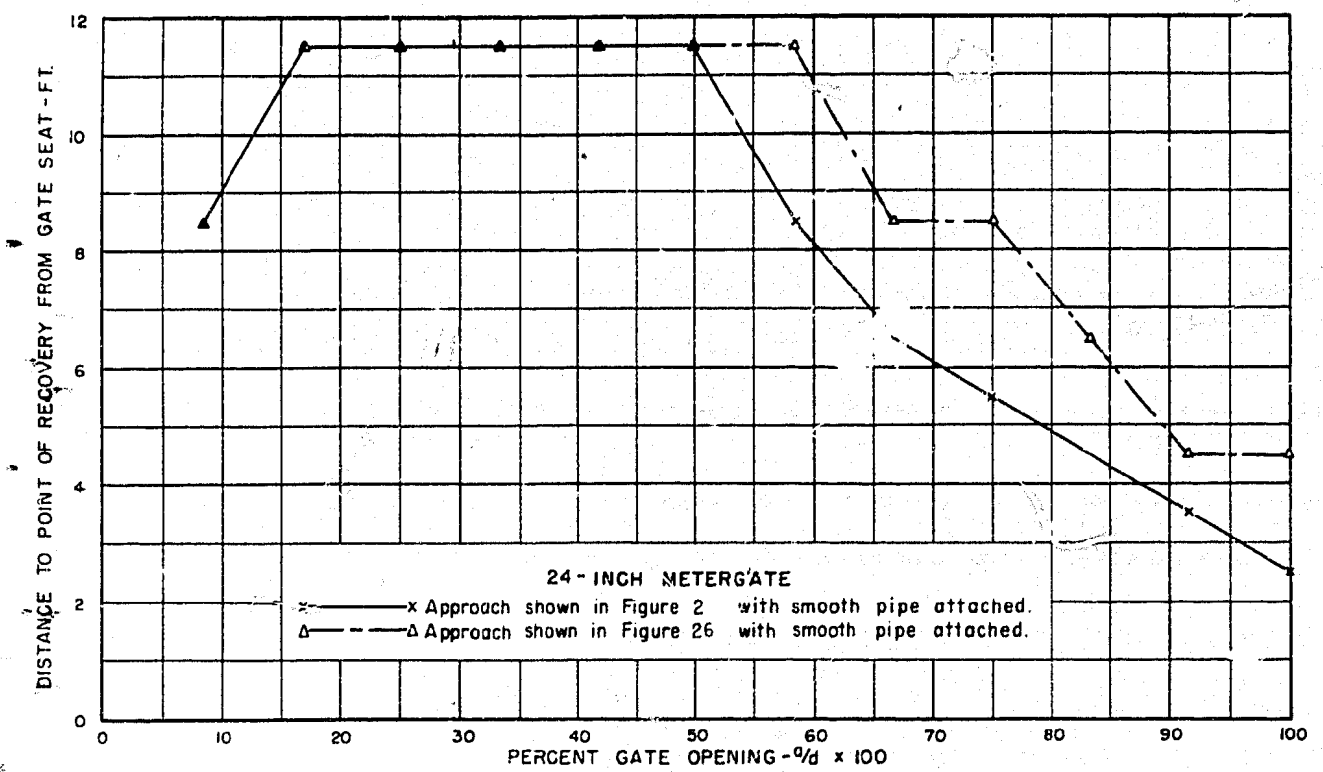
D - Difference in pressure head between the piezometer on top of pipe and piezometer offset 3½". Both piezometers one foot D.S. of gate seat - feet
ΔH - Difference in W.S. in measuring wells - feet

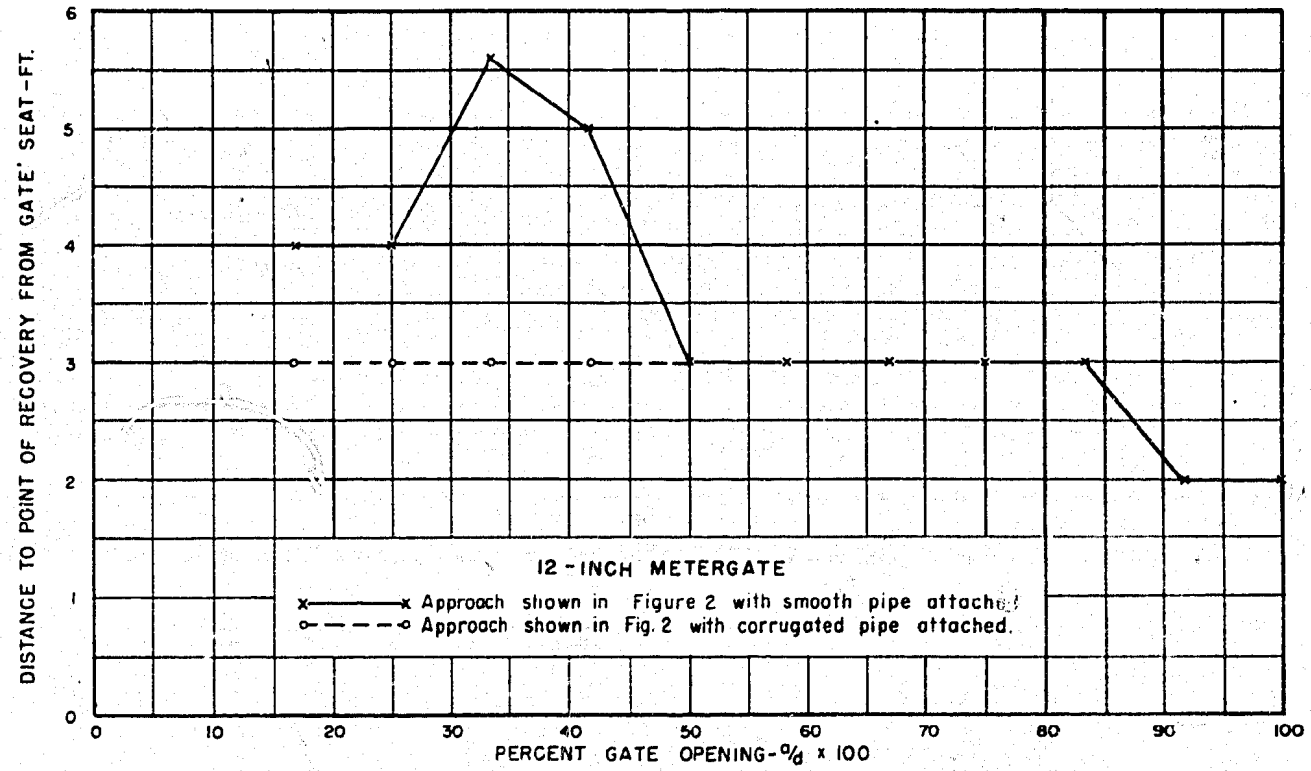


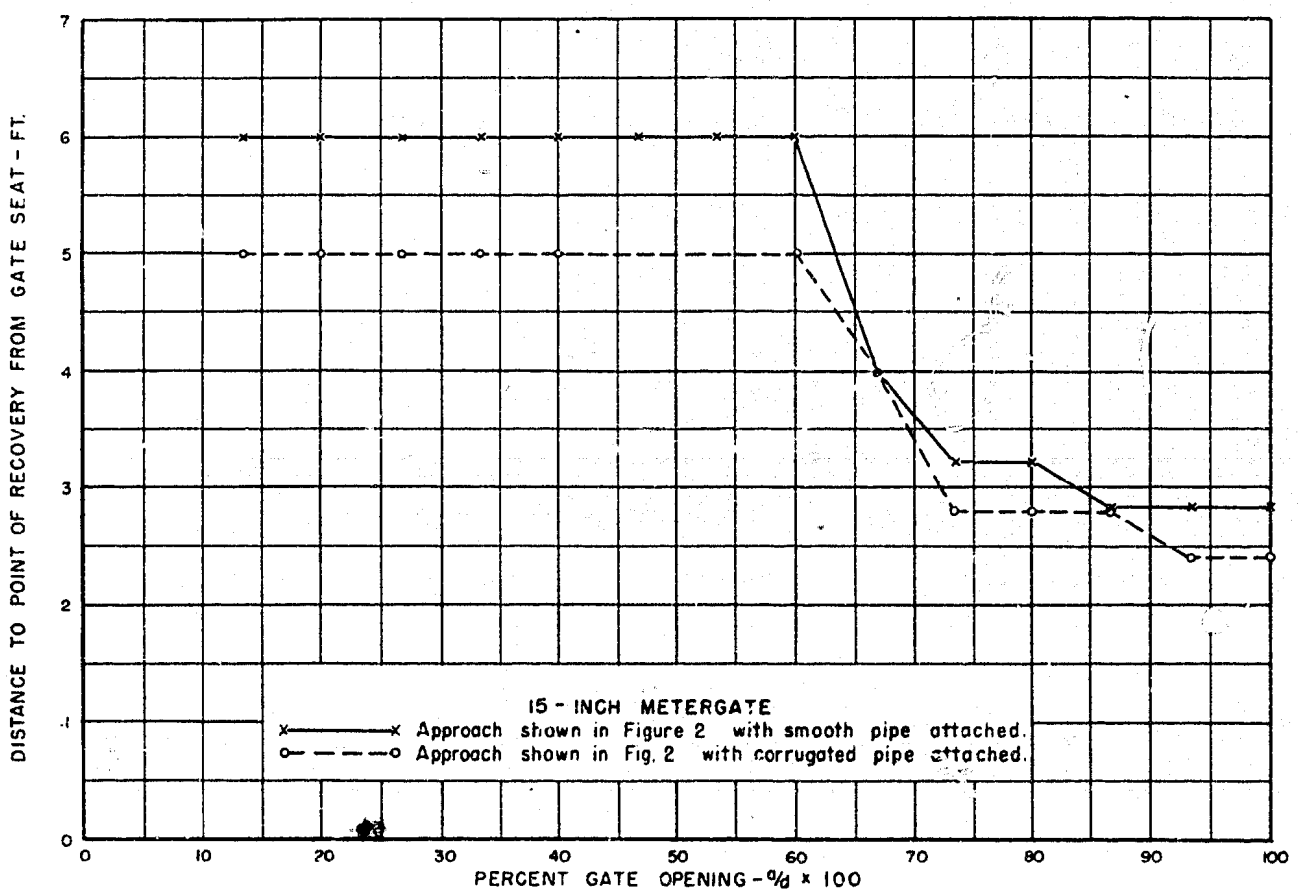
METERGATE STUDIES

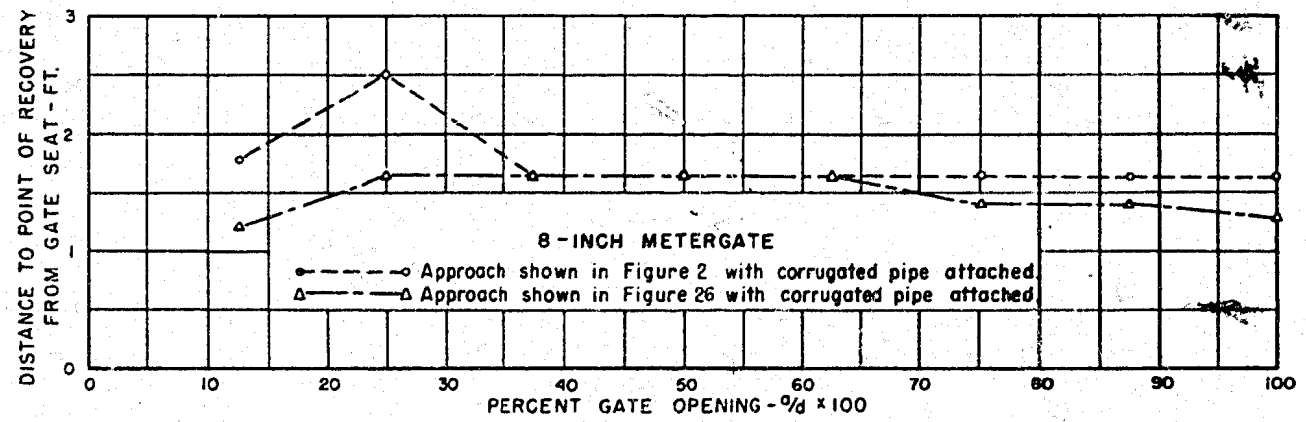
24 - INCH ARMCO METERGATE

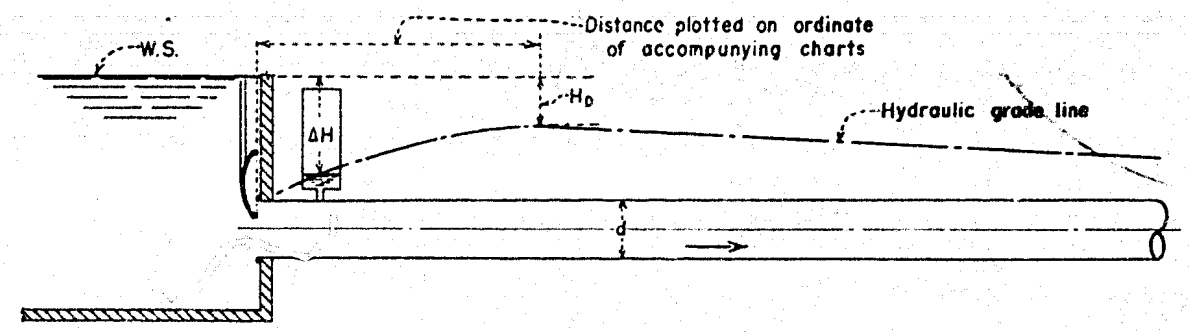
EFFECT OF MEASURING WELL TAP OFFSET









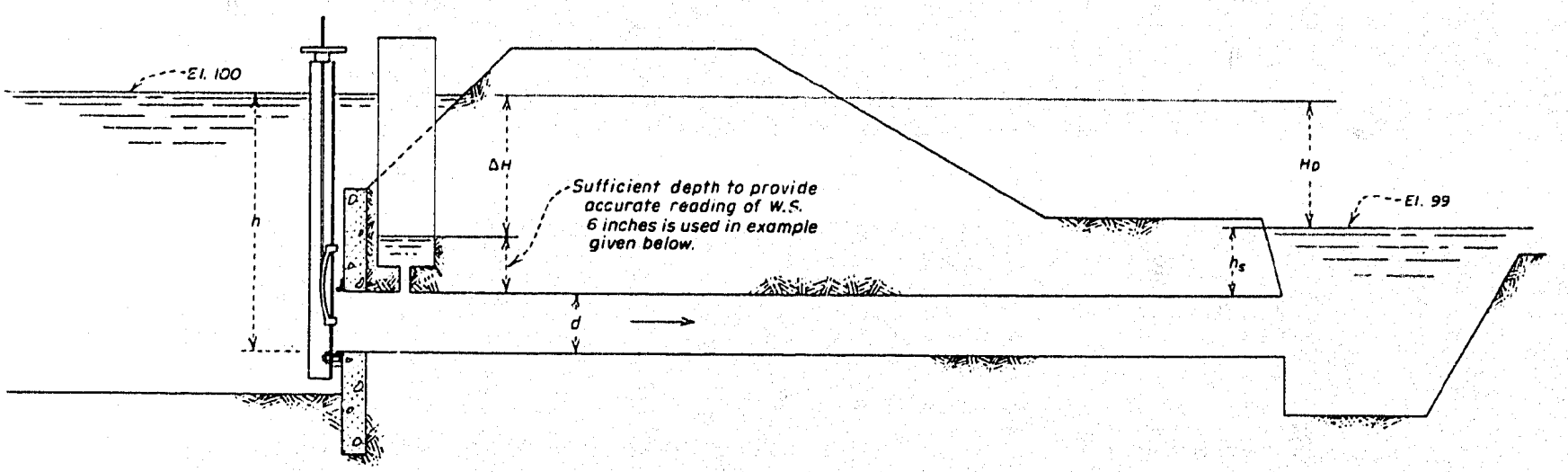


METERGATE STUDIES

8, 12, 15, 24 - INCH ARMCO METERGATES
LENGTH OF PIPE REQUIRED TO GET UNIFORM VELOCITY DISTRIBUTION

APPENDIX I

Computations Relating to Metergate Installation



SAMPLE COMPUTATIONS FOR A METERGATE INSTALLATION APPLYING PRESCRIBED LIMITATIONS

1. CONDITIONS GIVEN:
   Canal W.S. @ El. 100, Lateral W.S. @ El. 99, ∴ H_D = 1.0 ft., quantity to be delivered = 6 c.f.s., minimum W.S. in downstream well = 6 inches (above top inside surface of pipe), smooth pipe attached to gate.
2. DETERMINE SIZE OF METERGATE:
   Assume velocity which will not cause objectionable erosion at outlet, say 5 f.p.s. Area of pipe = $\frac{Q}{V} = \frac{6}{5} = 1.2$ ft.²
   Use 15-inch gate with area of 1.227 ft.²
3. DETERMINE MAXIMUM ΔH FOR INSTALLATION:
   From Figure 11 maximum pressure factor, $\frac{\Delta H}{H_D}$, for 15-inch gate with smooth pipe is 1.56 from which ΔH maximum = 1.56 ft.
4. DETERMINE MINIMUM SUBMERGENCE, h_s, REQUIRED TO PROVIDE W.S. IN DOWNSTREAM WELL ≧ 6 INCHES ABOVE PIPE.
   It is necessary to use the maximum pressure factor from the appropriate $\frac{\Delta H}{H_D}$ curve, Figure 11, to determine minimum h_s if the gate is to be used effectively over the complete range of openings. From above sketch, $h_s = (\Delta H + 0.5) - H_D = (1.56 + 0.5) - 1.0 = 1.06$ ft.
5. CHECK UPSTREAM SUBMERGENCE:
   $h = H_D + h_s + d = 1.0 + 1.06 + 1.25 = 3.31$ ft. ∴ $3.31 > 2d$
6. CHECK MAXIMUM CAPACITY OF GATE:
   At full gate opening $\frac{\Delta H}{H_D} = 1.08$ (Fig. 11) ∴ ΔH = 1.08 ft. ≈ $12\frac{15}{16}$".
   From mfg. tables Q = 7.87 c.f.s.

USE MFG. TABLES FOR DETERMINING DISCHARGE QUANTITIES.
FOR ΔH > 18" USE THE METHOD OUTLINED IN THE FOLLOWING PAGES OF THIS APPENDIX TO DETERMINE THE DISCHARGE.

METERGATE STUDIES
COMPUTATIONS FOR METERGATE INSTALLATION

FIGURE 29
REPORT HYD 314

The new rating tables prepared by the manufacturer are based on the plots shown on Figures 30 to 43. These plots were prepared by Colorado A&M College using the data from the Bureau of Reclamation and their own hydraulic laboratory.

Basically, these plots are the C_d versus R_e curves contained in Report No. Hyd-314 with a third grid system, the dimensionless parameter $D^2 \Delta Hg/\nu^2$ added to simplify the procedure for obtaining tabular values of the rating tables.

The procedure as outlined in a report titled "Calibration of Armco Metergates Model No. 101" published by The Colorado Agricultural Research Foundation, Colorado A&M College, Fort Collins, Colorado, is given below:

"In general, to find the discharge Q for a given head difference ΔH, for a given size metergate, and a given gate opening, the following procedure can be utilized; solve the dimensionless parameter $D^2 \Delta Hg/\nu^2$ by substituting the pipe diameter in feet for D; the given head difference in ft. for ΔH; 32.2 ft. per sec. per sec. for acceleration of gravity g; and 1.21×10^{-5} sq. ft. per sec. based on a temperature of 60° F selected as the average condition for the United States, for kinematic viscosity ν. With this value for $D^2 \Delta Hg/\nu^2$, enter the figure which applies for the given gate size, and follow down the proper sloping line to the left until the curve representing the given gate opening is intersected. Finally, drop vertically down from this point, to read the value of Reynolds number R_e from which either V or Q may be computed by the following equations:

$$R_e = \frac{VD}{\nu} = 0.826 \times 10^5 \, VD$$

or

$$R_e = \frac{4}{\pi} \frac{Q}{\nu D} = 1.052 \times 10^5 \frac{Q}{D}"$$

For example,

Metergate size	42-inch
Gate opening	20 inches
Difference in head (ΔH)	4 inches

then

$$D^2 \Delta Hg/\nu^2 = \frac{12.22 \times .33 \times 32.2}{1.46 \times 10^{-10}} = 9 \times 10^{11}$$

Entering with this value of 9×10^{11} for the parameter on Figure 42 a value of R_e of 5.50×10^5 is obtained for the 20-inch gate opening. From the relationship

$$R_e = 1.052 \times 10^5 \frac{Q}{D}$$

the discharge Q is

$$Q = \frac{3.5 \times 5.50 \times 10^5}{1.052 \times 10^5} = 18.3 \text{ cfs}$$

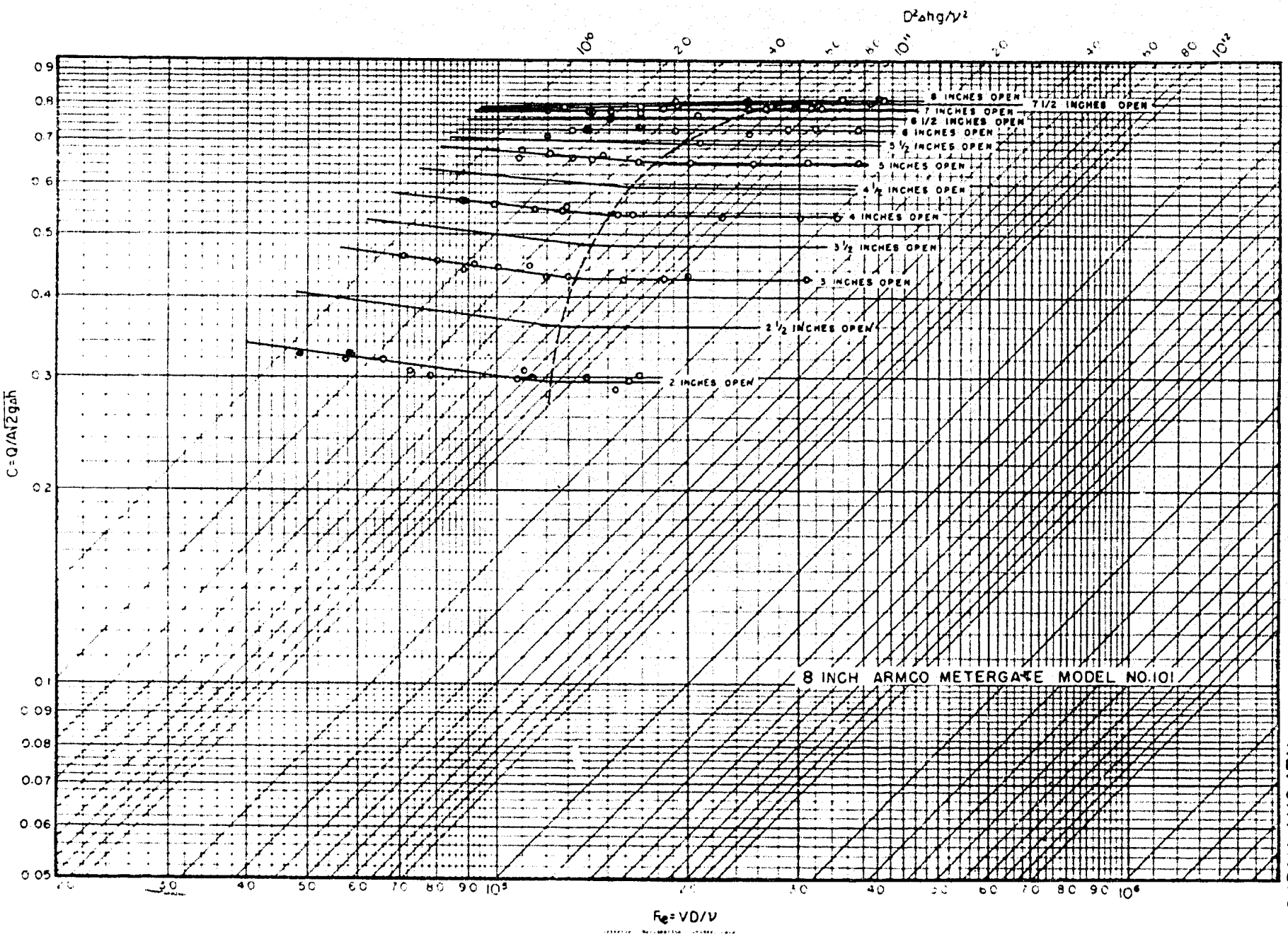


FIGURE 30
REPORT HYD. 314

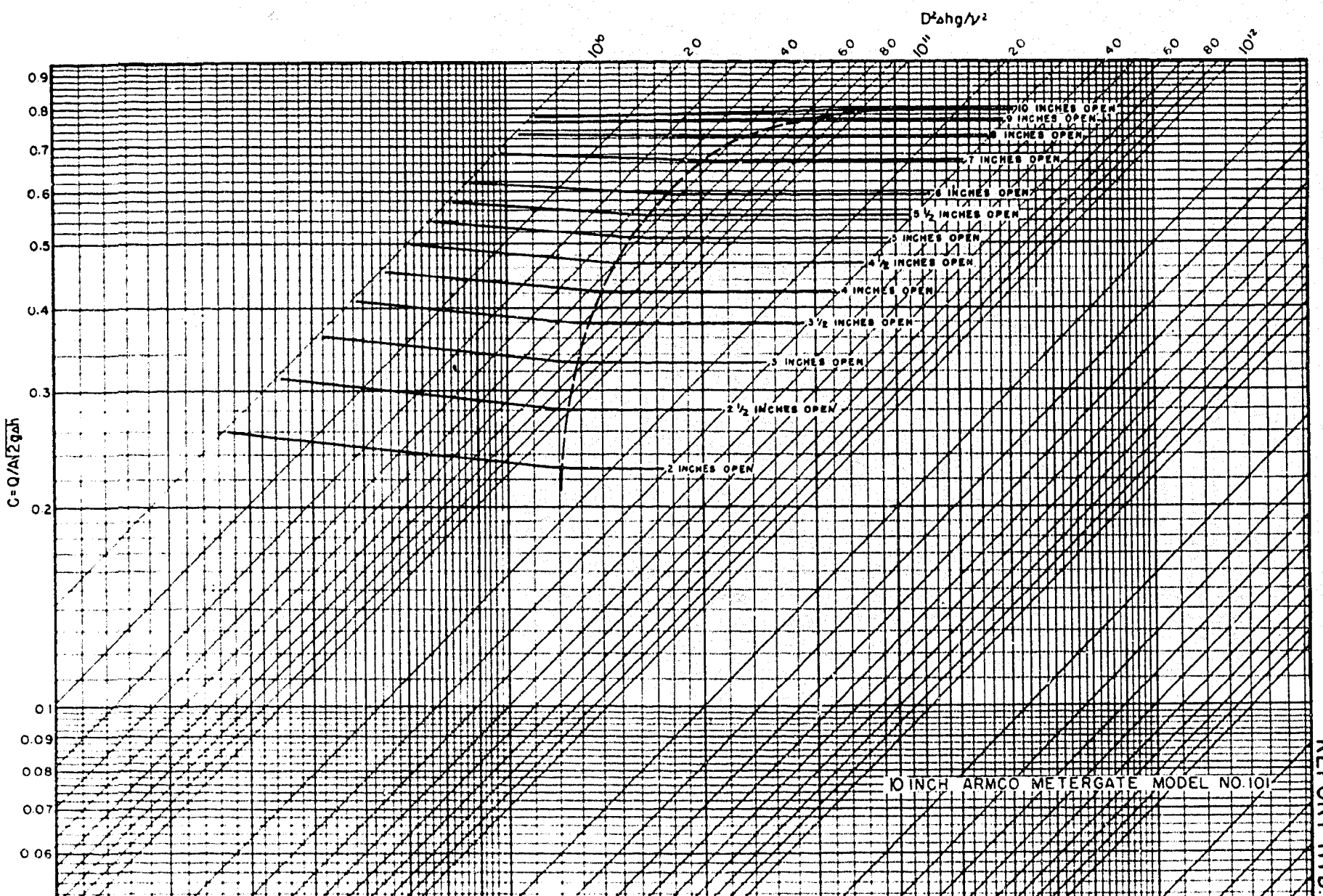


FIGURE 31
REPORT HYD. 314

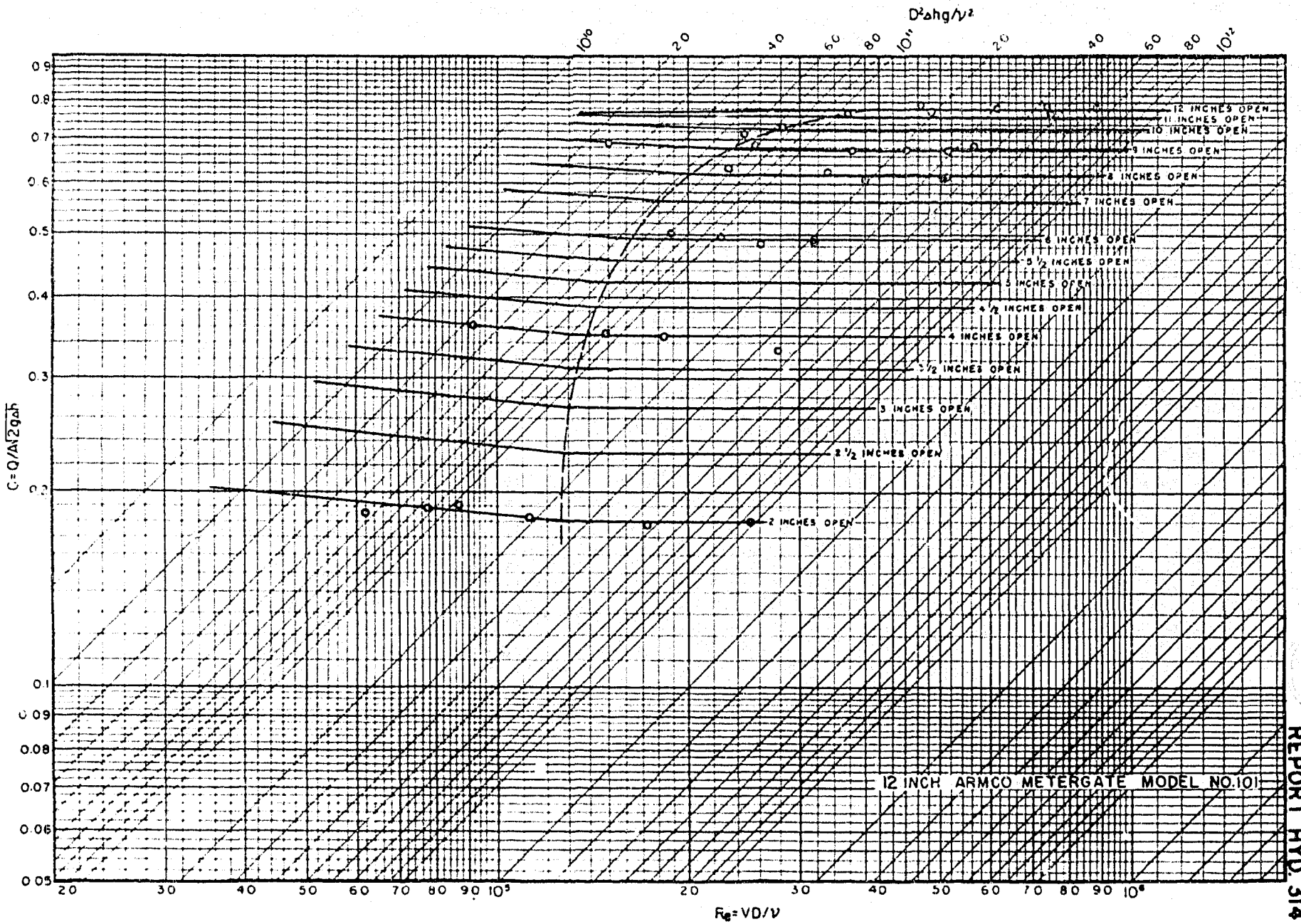


FIGURE 32
REPORT HYD. 314

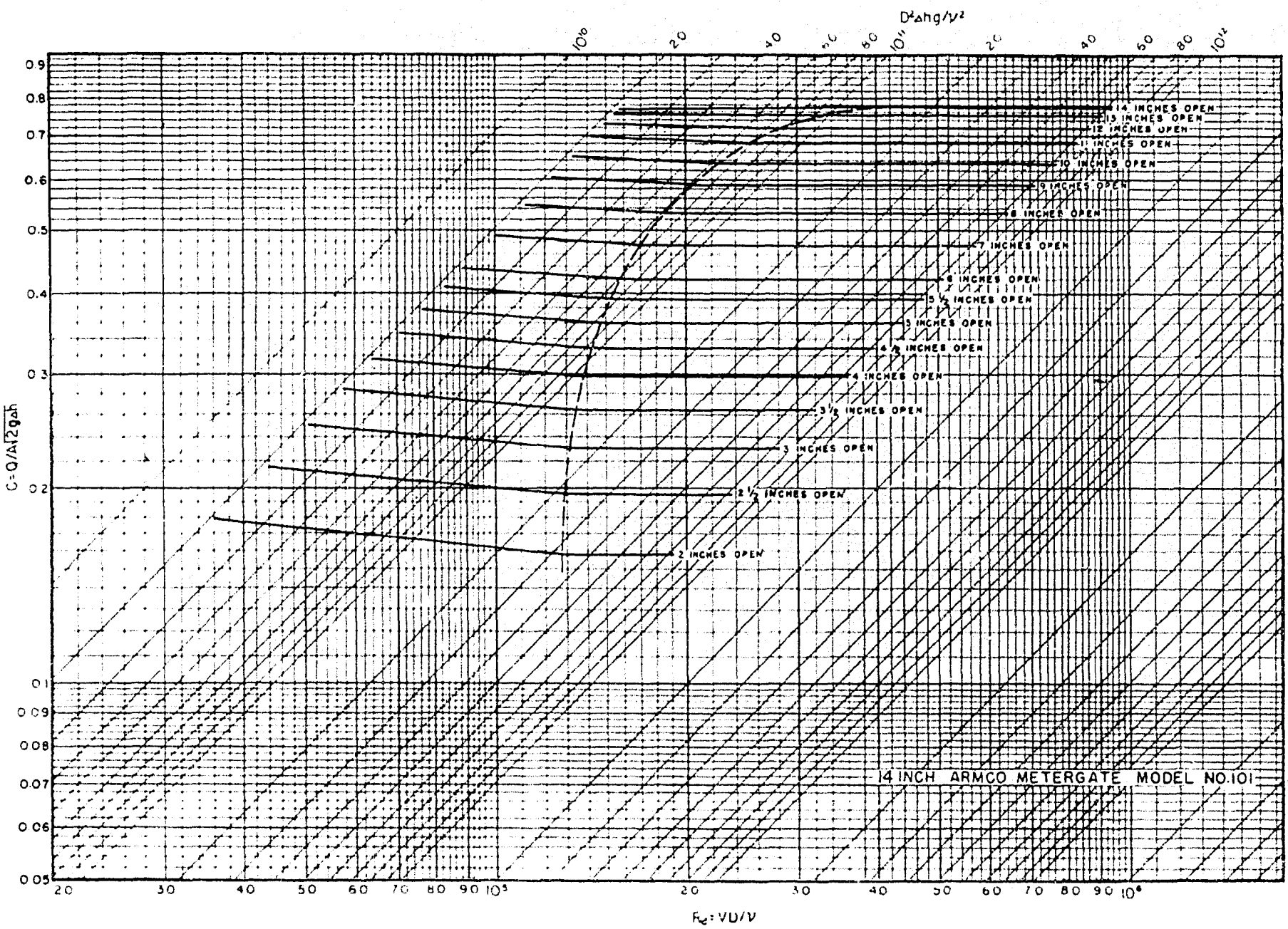


FIGURE 33
REPORT HYD.314

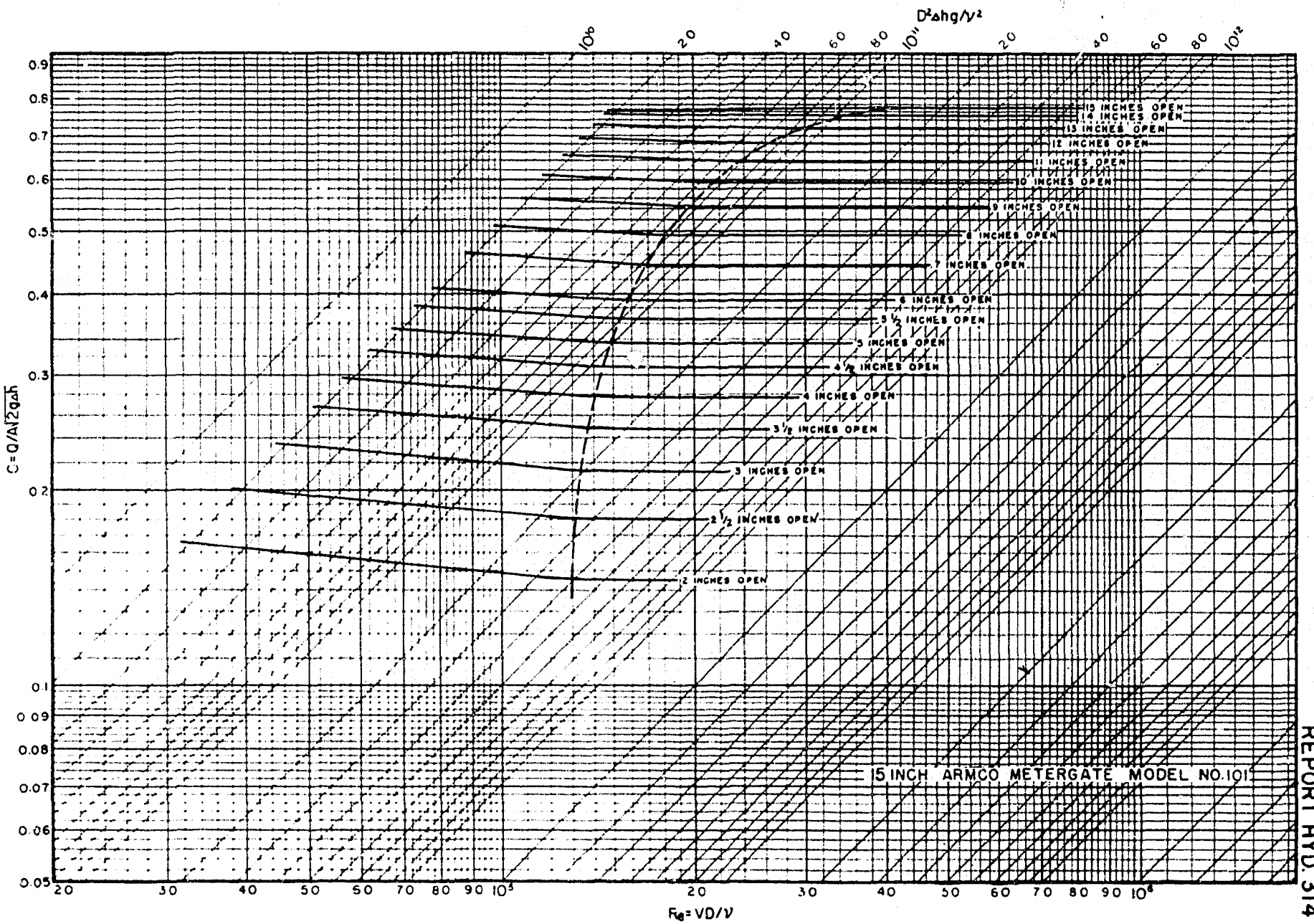


FIGURE 34
REPORT HYD. 314

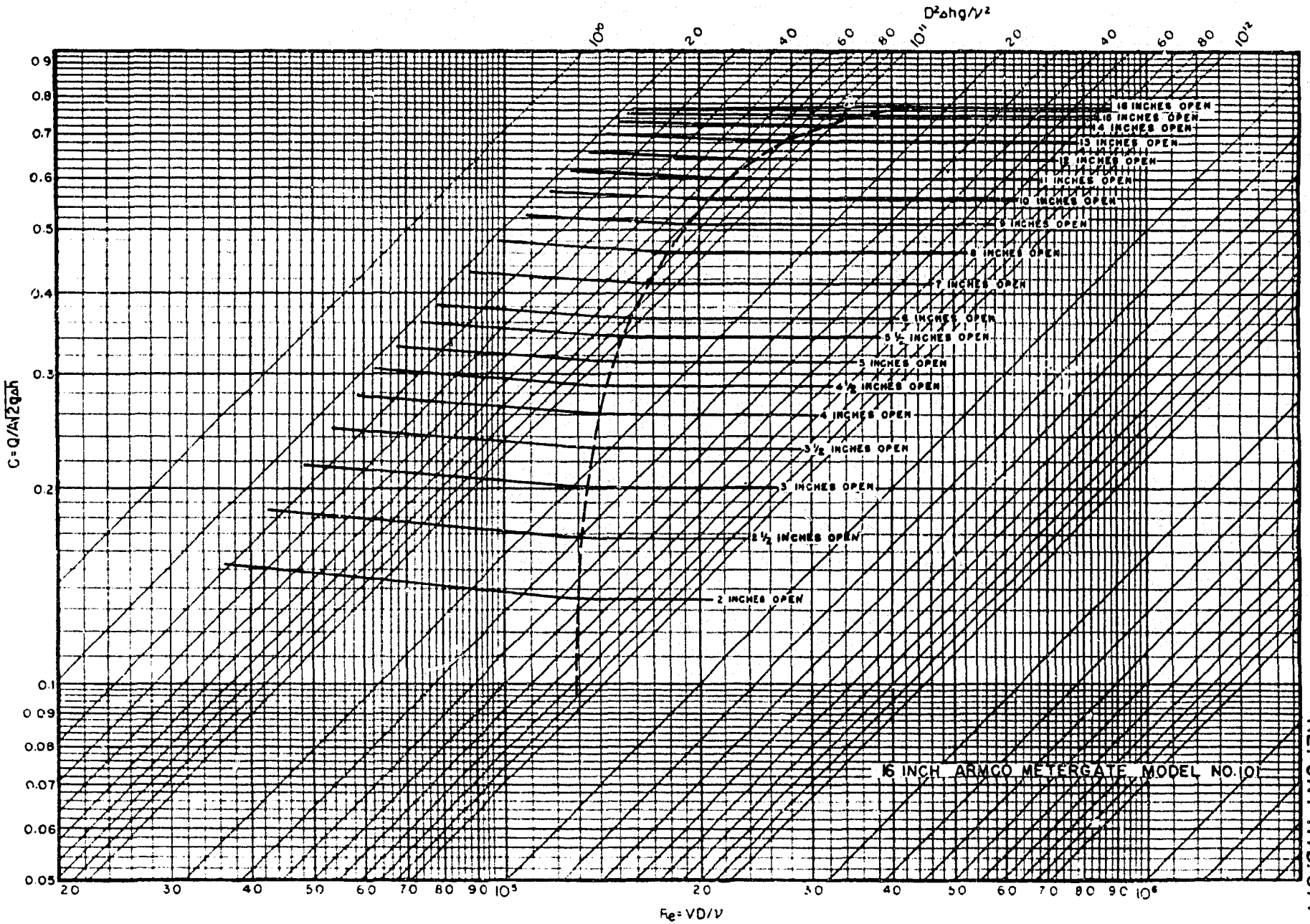


FIGURE 35
REPORT HYD. 314

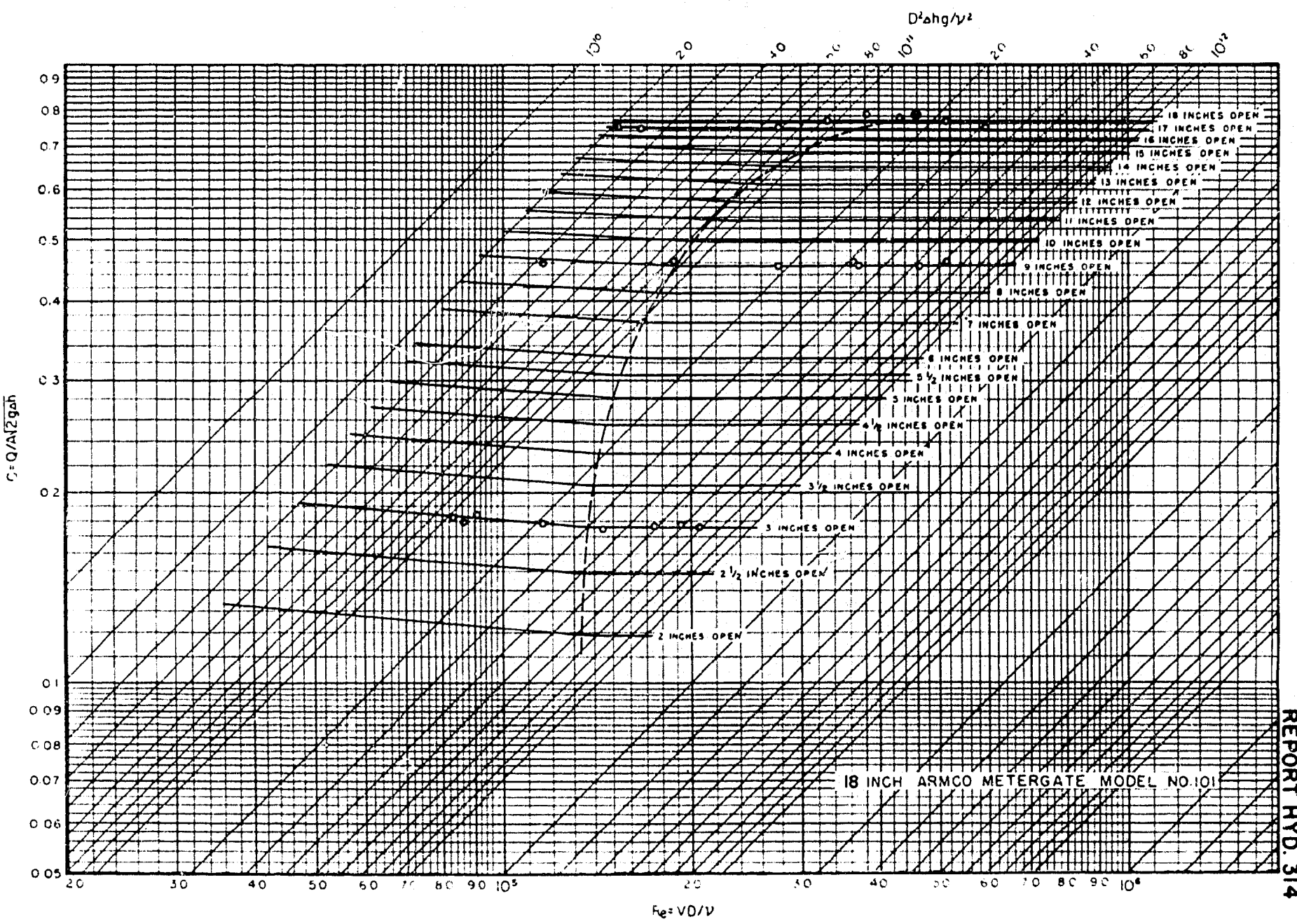


FIGURE 36
REPORT HYD. 314

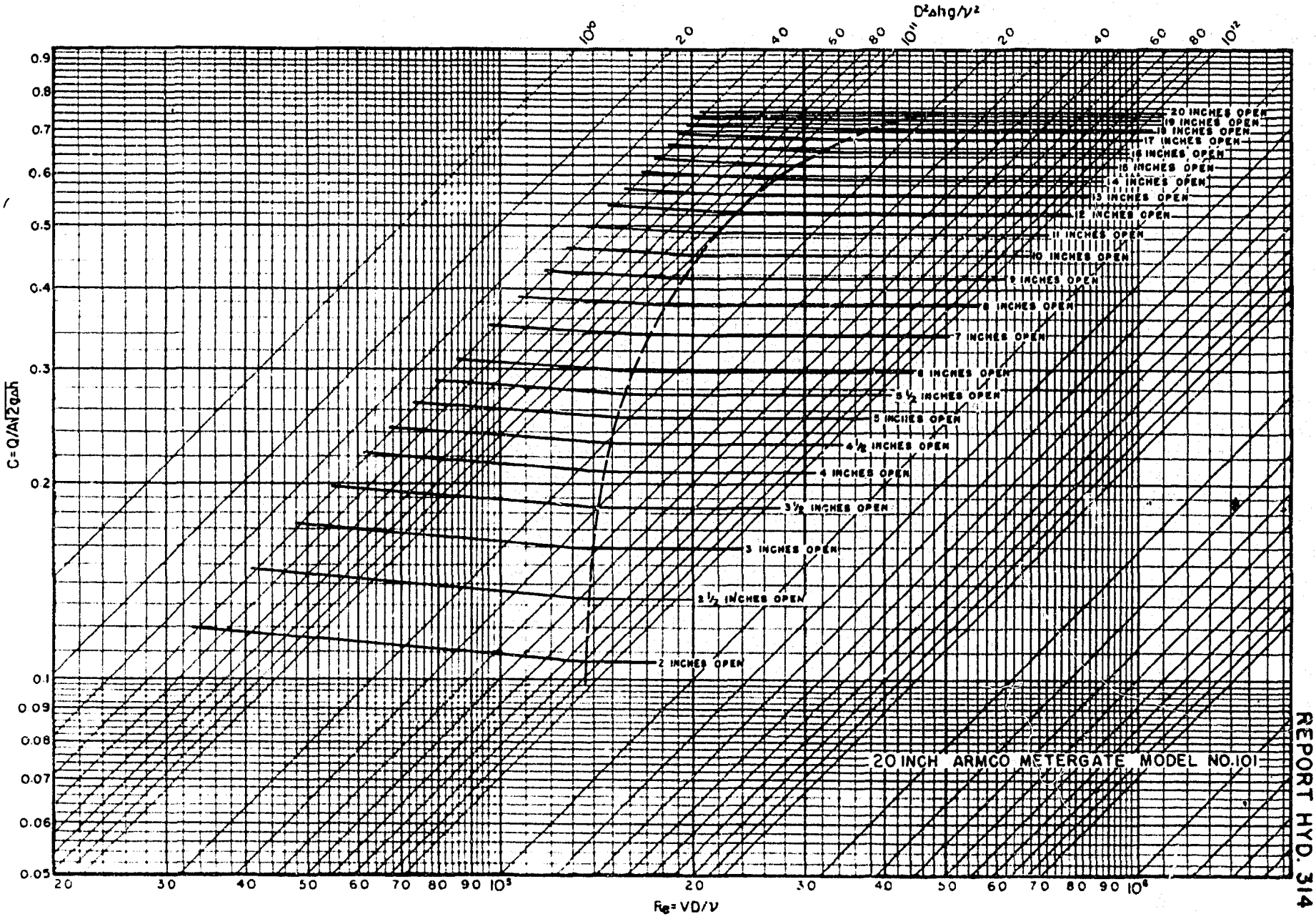


FIGURE 37
REPORT HYD. 314

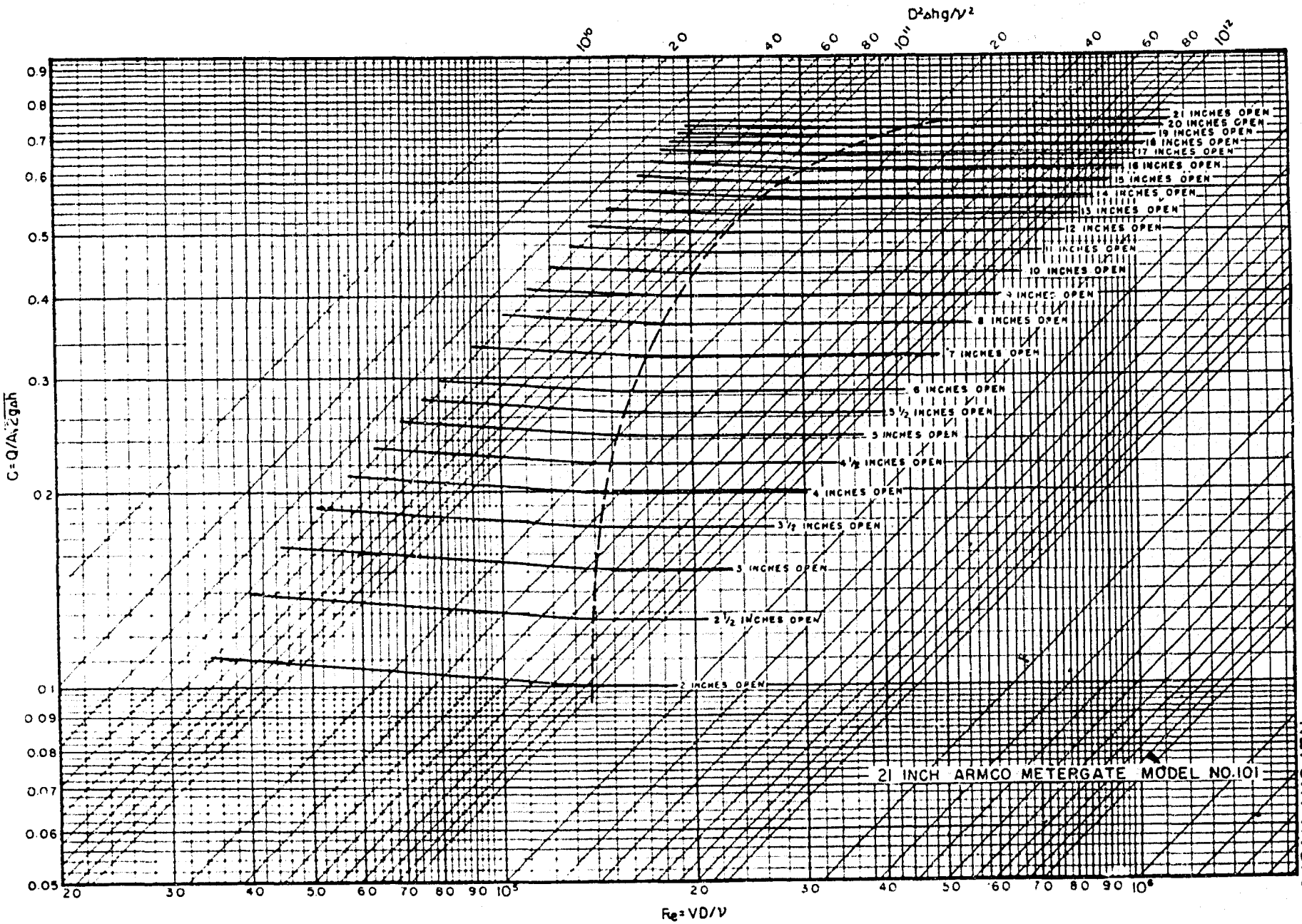


FIGURE 38
REPORT HYD. 314

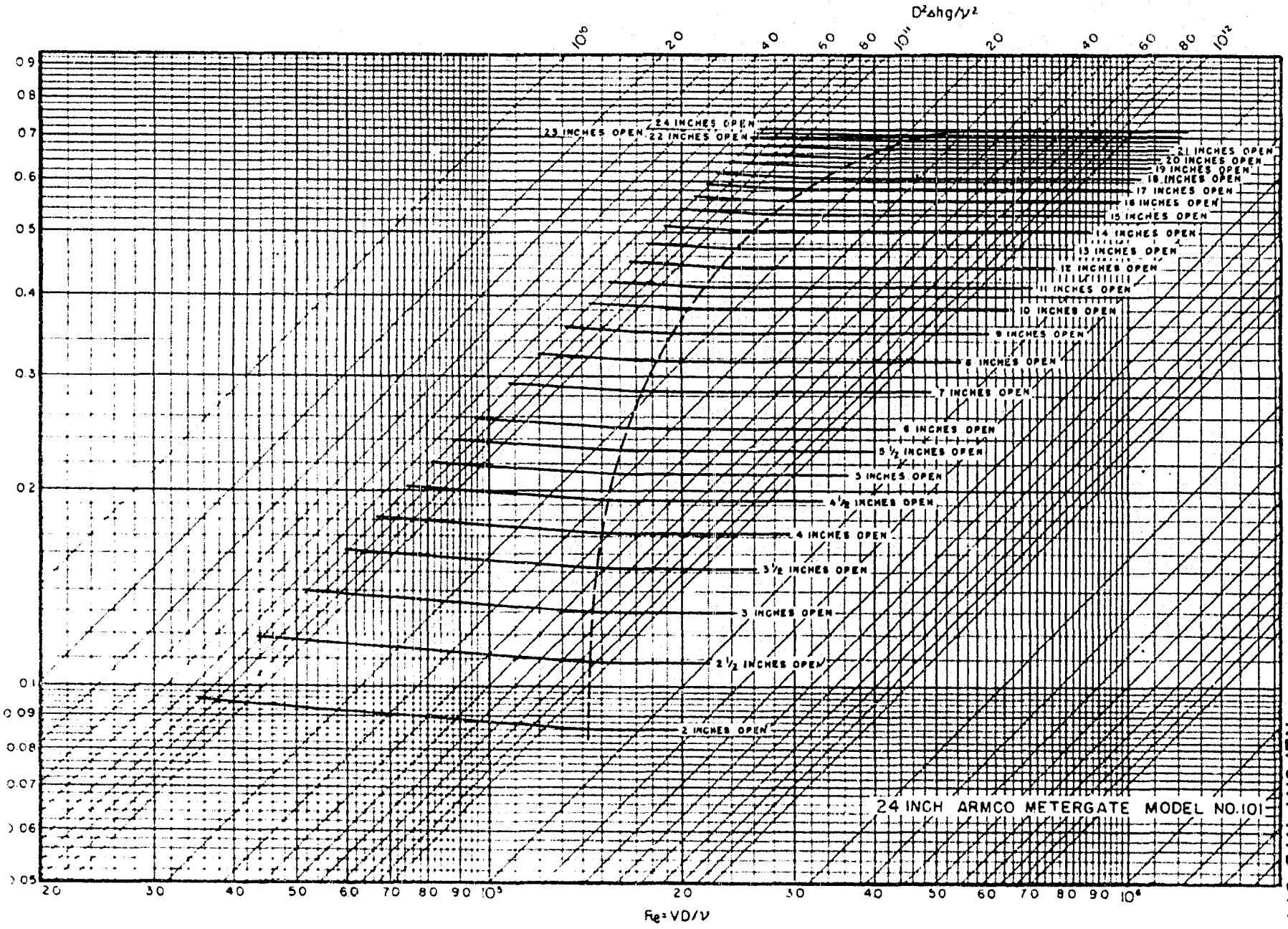


FIGURE 39
REPORT HYD 314

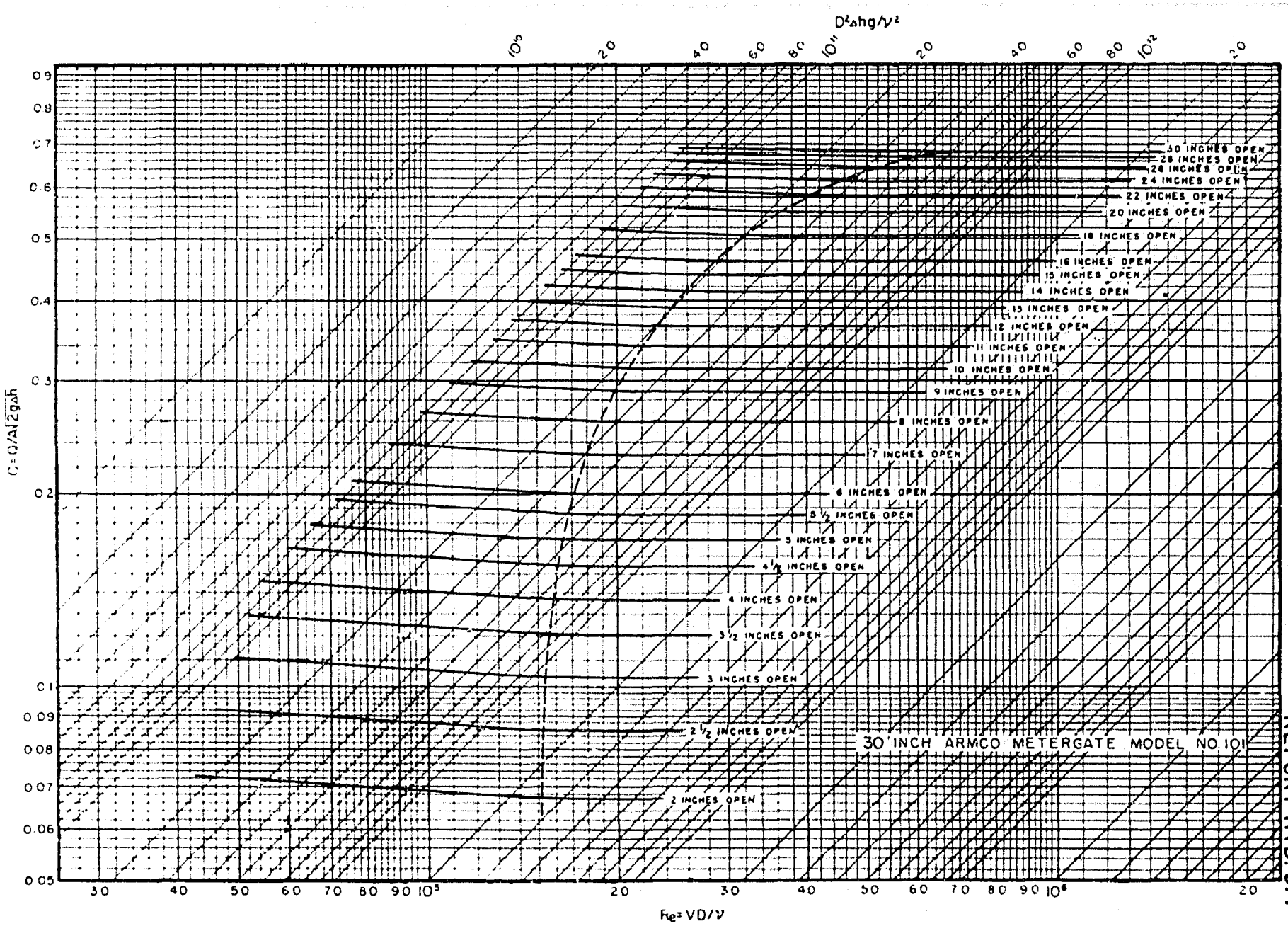


FIGURE 40
REPORT HYD. 314

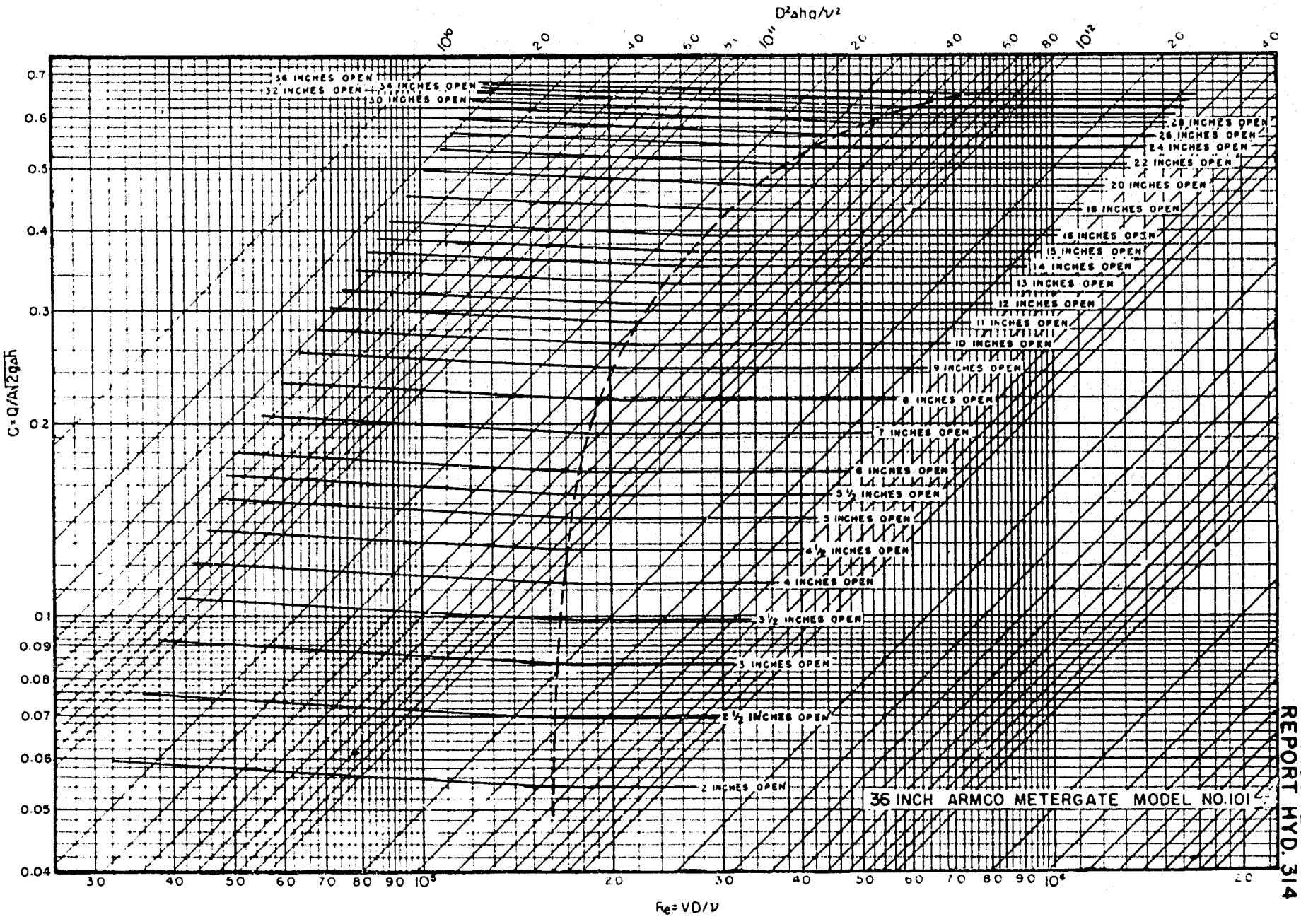


FIGURE 41
REPORT HYD. 314

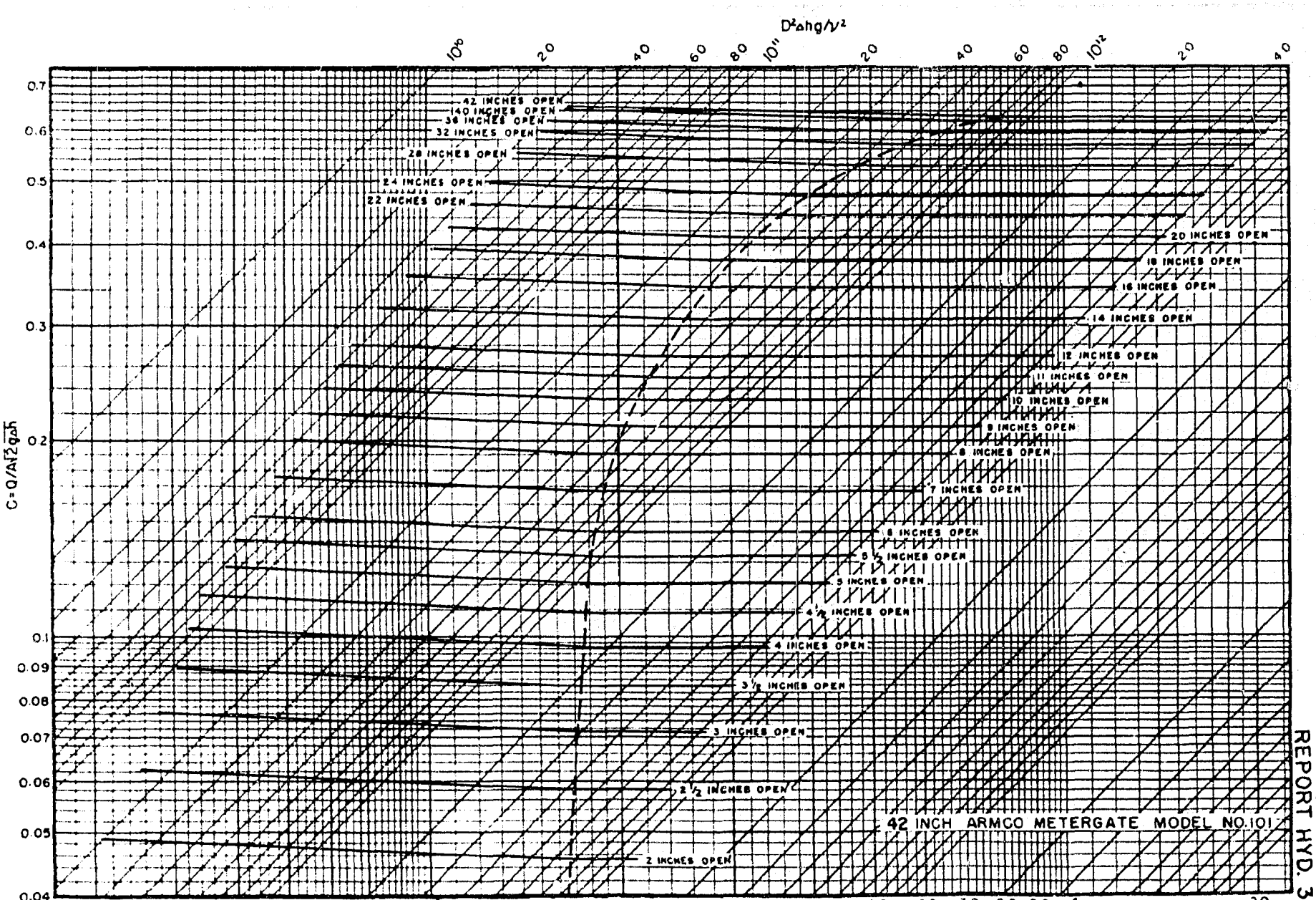


FIGURE 42
REPORT HYD. 314

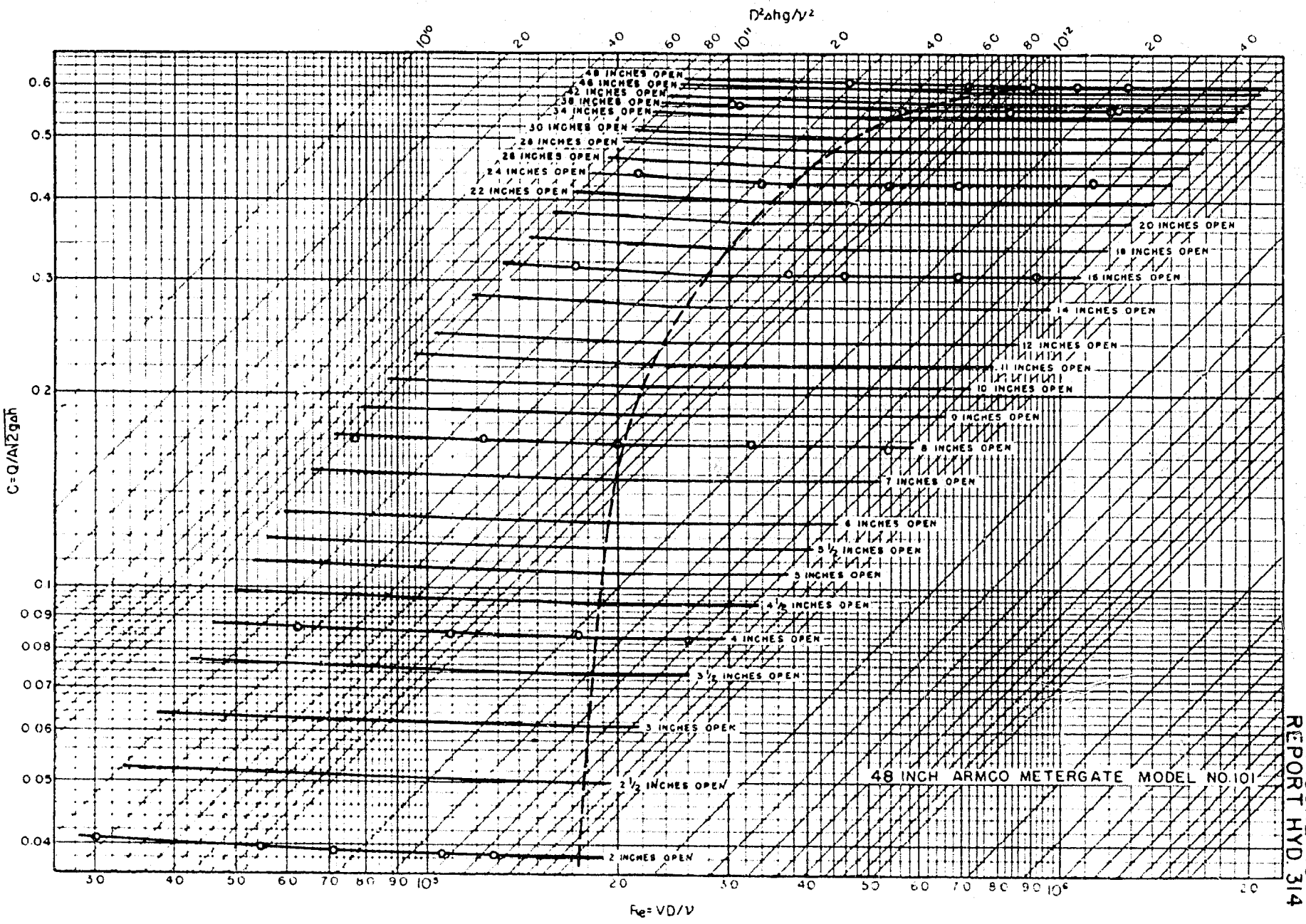


FIGURE 43
REPORT HYD 314